

[54] **DRIVE TRAIN FOR LOGGING-WHILE-
DRILLING TOOL**

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175/50, 138/45, 251/81

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33/205, 307; 138/45, 46; 175/40, 45, 46, 50;
259/1, DIG. 43; 73/151

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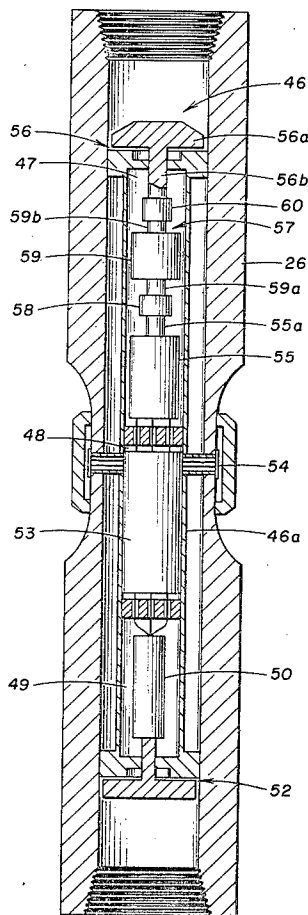
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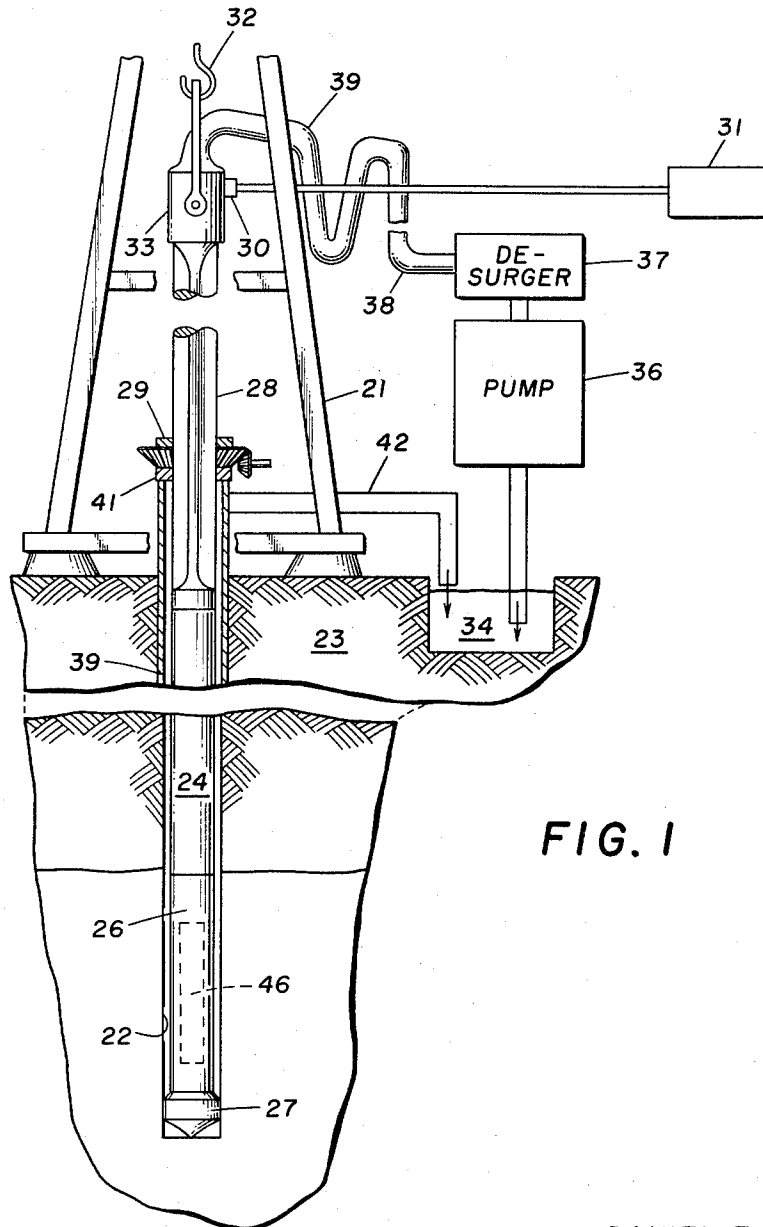
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ABSTRACT

An improved drive train for coupling a motor to a signal generating, rotary type valve in a logging-while-drilling tool. The drive train includes a double planetary, speed reducing transmission, the input shaft of which is coupled to the motor by an automatically releasable clutch to prevent damage in the event the valve becomes jammed. The output shaft of the transmission is coupled to the rotor of the valve by means of a flexible coupling which reduces the reversing peak torque loads created by operation of the valve.

7 Claims, 6 Drawing Figures

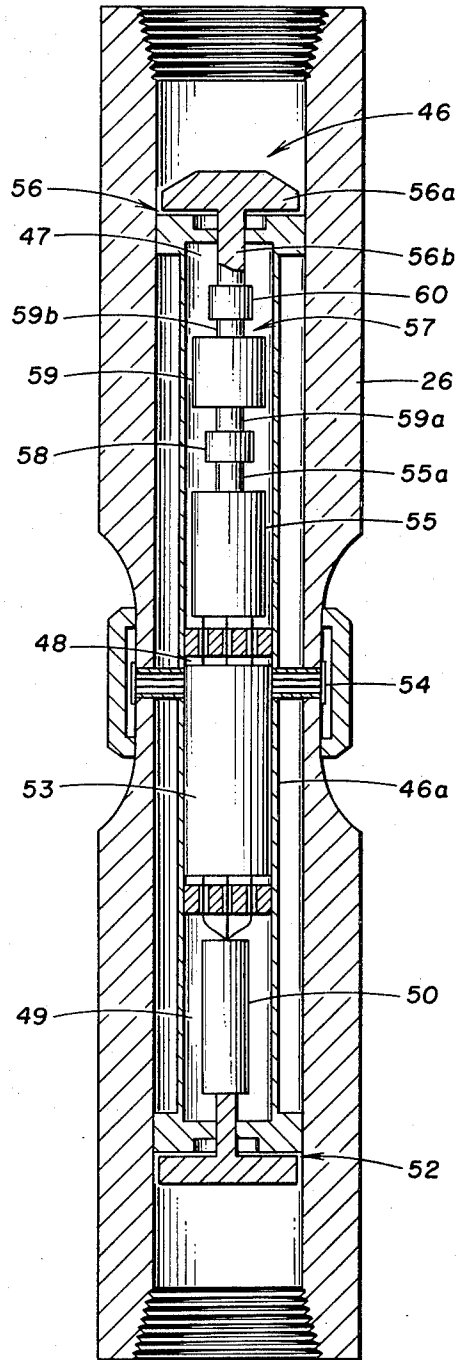




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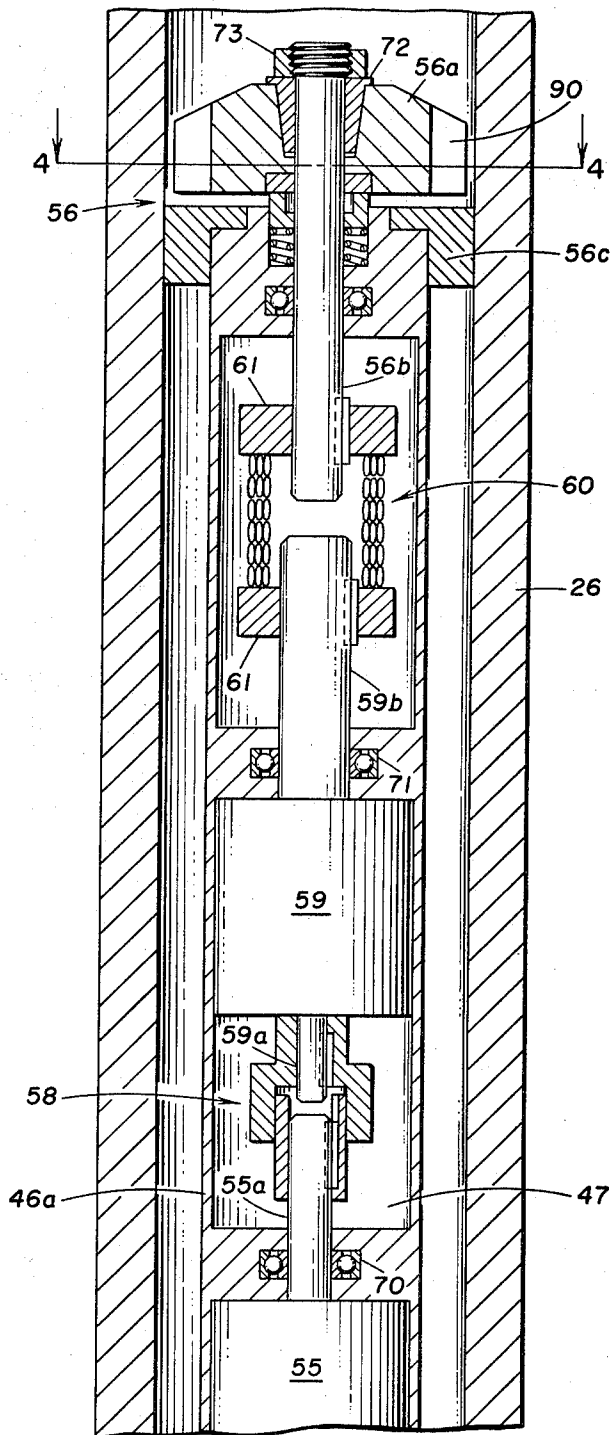
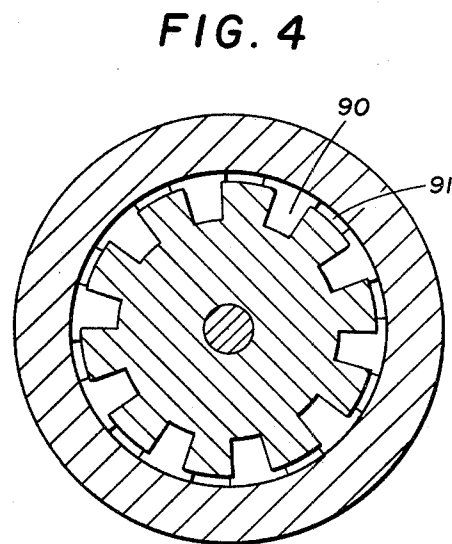
FIG. 2



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FIG. 5

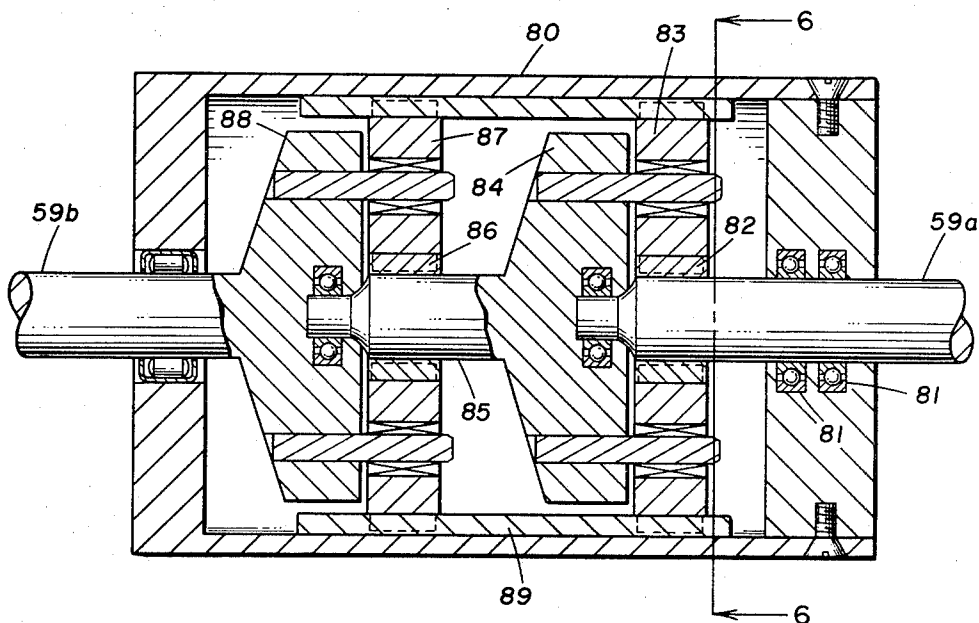
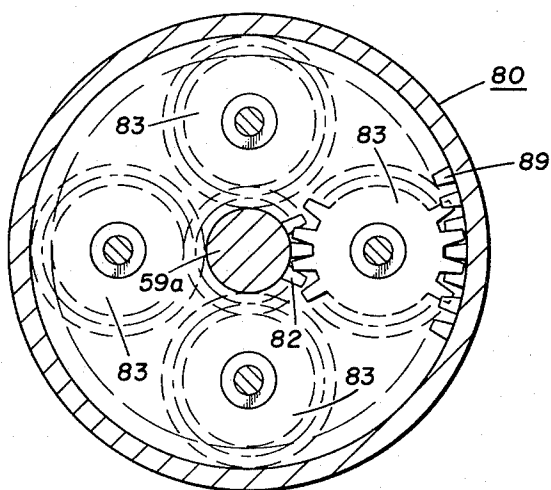


FIG. 6



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DRIVE TRAIN FOR LOGGING-WHILE-DRILLING TOOL

BACKGROUND OF THE INVENTION

The present invention relates to a logging-while-drilling tool and more particularly relates to an improved drive train in a logging-while-drilling tool which utilizes a motor actuated rotary valve positioned in the drilling fluid to generate a pressure wave signal representative of a "logged" condition.

The desirability of a system which is able to measure downhole drilling parameters and/or formation characteristics and transmit them to the surface while the actual drilling of an earth well is being carried out has long been recognized. Several such systems have been proposed and are commonly referred to as "logging-while-drilling" systems. In logging-while-drilling systems, one of the major problems exists in finding a means for telemetering the desired information from a downhole location to the surface and having it arrive in a meaningful condition.

In this regard, it has been proposed to telemeter the desired information by means of a pressure wave signal generated in and transmitted through the circulating mud system normally associated with rotary drilling operations. The pressure wave signal which is representative of a particular piece of desired information is generated in the mud downhole near the drill bit by a generating tool and the wave travels up the hole through the mud to a signal processor at the surface. One logging-while-drilling system utilizing this technique of telemetry is disclosed and fully described in U.S. Pat. No. 3,309,656 to John K. Godbey, issued Mar. 14, 1967.

In a tool of the type disclosed in U.S. Pat. No. 3,309,656, a rotary valve is positioned in the circulating mud path near the drill bit. A motor in the tool is energized in response to a measured piece of desired information to open and close said valve at a rate which will generate a pressure wave in the mud representative of the measured information.

The motor is connected to the valve by means of a drive train which includes a speed reducing transmission. Since the overall length and diameter of the logging-while-drilling tool is limited, this transmission must be capable of substantially reducing the rotational speed of the motor while occupying a minimum volume and at the same time must be rugged enough to withstand the heavy load demands made on the transmission. Further, the transmission must be resistant to undue wear since any play or backlash in the gears of the transmission can seriously affect the instantaneous rotational relationship between the motor and the valve which in turn affects the character of the generated pressure wave.

The signal generating valve is similar to a power turbine in that it has a stator and a rotor which rotate relative to each other. When the valve is in an open position, slots in the rotor and stator are aligned to allow flow therethrough. When the valve is in a closed position, the slots are misaligned to block flow. When the tool is in operation, the drive train experiences loads other than those applied by the motor. These loads develop from the operation of the valve as it constantly rotates between its open and closed positions. This constantly reversing loading produces peak torques that

must be compensated for in the drive train before they are applied to the transmission to prevent undue fatigue of the transmission. Also, these torques may cause premature failure of the shaft connecting the transmission to the rotor if they are uncompensated for.

Another problem for the drive train results from large debris, e.g., chunks of wood or the like, which may become entrained in the drilling mud. This debris is circulated down the drill string and can become lodged in the slots through the rotor and stator of the valve, thereby locking the rotor against rotation. If this occurs and the motor in the tool continues to run, serious damage to the motor and drive train can result. Therefore, the drive train should contain a means for preventing such damage in the event the valve becomes locked.

SUMMARY OF THE INVENTION

The present invention provides an improved drive train for a logging-while-drilling tool of the type having a motor-actuated rotary valve to impart a pressure wave signal to the drilling mud.

The improved drive train of the present invention connects the motor to the rotary valve in the logging-while-drilling tool and includes a compact, heavy duty transmission for reducing the relatively high speeds of the motor to the much lower, operational speeds of the valve. The drive train also includes means to reduce the reversing peak torque loads developed by the opening and closing of the valve and means to prevent damage to the motor and drive train in the event the valve jams against rotation.

Structurally, the present drive train comprises a clutch means positioned between the output shaft of the drive motor and the input shaft of a speed reducing transmission. The clutch means provides a positive driving connection between the shafts under normal operating conditions but automatically disengages to allow relative rotational movement between the shafts in the event that one of the shafts becomes locked. The transmission is compact in both length and diameter but at the same time is rugged and capable of handling the heavy loads applied thereto. The transmission has a double planetary gear arrangement which provides the necessary speed reduction between the motor and the rotor of the valve.

The output shaft of the transmission is coupled to the shaft of the rotor of the valve by means of a flexible coupling. The flexible coupling not only provides a positive driving connection between the two shafts, but also has the proper compliance to reduce the high peak torques produced by the reversing loads on the shafts which are developed by the operation of the valve.

BRIEF DESCRIPTION OF THE DRAWINGS

The actual construction, operation, and the apparent advantages of the invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

FIG. 1 is a schematic elevation of a rotary drilling apparatus including in vertical section a well containing a drill string in which the present invention is employed;

FIG. 2 is a schematic elevation, partly in section, of a portion of the drill string of FIG. 1 having a logging-

while-drilling tool mounted therein which utilizes the present invention;

FIG. 3 is a detailed sectional view of the upper portion of FIG. 2;

FIG. 4 is a sectional view taken along section 4—4 of FIG. 3;

FIG. 5 is a detailed sectional view of the transmission of the present invention; and

FIG. 6 is a sectional view taken along section line 6—6 of FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawings, FIG. 1 discloses the present invention as used in a logging-while-drilling system which is incorporated in a rotary drilling apparatus. A derrick 21 is disposed over a well 22 being formed in the earth 23 by rotary drilling. A drill string 24 is suspended within the well and has a drill bit 27 at its lower end and a kelly 28 at its upper end. A rotary table 29 cooperates with kelly 28 to rotate string 24 and bit 27. A swivel 33 is attached to the upper end of kelly 28 which in turn is supported by hook 32 from a traveling block (not shown). This arrangement not only supports the drill string 24 in an operable position within well 22 but also forms a rotary connection between the source of circulating drilling fluid, such as mud, and the drill string 24. It should be understood that "mud" as used throughout this disclosure is intended to cover those fluids normally used in rotary drilling operations.

The pump 36 transfers drilling mud from a source such as pit 34 through desurger 37 into mudline 38. Desurger 37 is adapted to reduce the pulsating effect of pump 36 as is well known in the art. The mud flows through mudline 38, flexible hose 39, swivel 33, drill string 24, and exits through openings (not shown) in drill bit 27 to pass outwardly into well 22. The mud then circulates upward carrying drill cuttings with it through the annulus between the well and drill string 24 to the surface of the earth 23. At the surface, well head 41 is secured to casing 40 which is cemented in the well 22. Pipe 42 is connected to casing 39 for returning the mud to pit 34.

As schematically illustrated in FIGS. 1 and 2, a logging-while-drilling tool 46 is located in drill collar 26 which forms a part of the lower end of drill string 24 near bit 27. Tool 46 has a motor-actuated rotary valve which periodically interrupts the drilling fluid flowing through the valve to thereby generate a pressure wave in the fluid which is representative of a measured downhole condition. This is the type of logging-while-drilling tool which is disclosed and described in U.S. Pat. No. 3,309,656. The present invention is directed to an improved drive train for coupling the motor to the valve. However, in order to fully understand and appreciate the present invention, a brief description of tool 46 will be set forth.

A transducer means which is capable of measuring a desired downhole condition and converting the measurement to an electrical signal is positioned downhole on or near tool 46. As illustrated, transducer means 54, e.g., a strain gauge, is positioned on drill collar 26 to measure the downhole weight on bit 27. The signal from transducer means 54 is applied to electronic

package 53 which is sealed in compartment 48 of tool housing 46a. For an example of such an electronic package, see U.S. Pat. No. 3,309,656. Circuitry in package 53, in response to the signal from means 54, allows a defined amount of power from electric power generator 50 in compartment 49 of housing 46a to flow to variable speed, electric motor 55 in compartment 47 of housing 46a. A turbine 52 driven by the mud flow rotates generator 50 to produce electrical power. Motor 55 in response to the amount of electricity passing through package 53, will drive rotor 56a of signal generating valve 56 through improved drive train 57 at the rotational speed necessary to generate a pressure wave signal in the mud which is representative of the measured condition.

As shown schematically in FIG. 2 and more in detail in FIG. 3, drive train 57 comprises a speed reducing transmission 59, a clutch means 58 which couples output shaft 55a of motor 55 with input shaft 59a of transmission 59, and flexible coupling means 60 which couples output shaft 59b of transmission 59 to rotor shaft 56b. Drive train 57 will now be described in detail for a better understanding of the present invention.

Looking to FIG. 3, motor 55 is mounted in upper compartment 47 of tool housing 46a. Output shaft 55a of motor 55 is journaled by means of bearings 70 in housing 46a and is coupled to input shaft 59a of transmission 59 by clutch means 58. Clutch means 58 may be of any type which provides a positive driving connection between the shafts under normal operating conditions but allows the two shafts to move relative to each other in the event that one shaft becomes locked against rotation. Preferably the clutch is a nonfriction, positive-cog type clutch which will release in either rotational direction when a predetermined torque is exceeded by either shaft relative to the other. Clutches of this type are commercially available, e.g., "Torq-Tender" sold by Helland Research and Engineering, Inc. of Navarre, Minnesota. The purpose of providing clutch 58 in drive train 57 will be set forth below in the description of operation of the present invention.

Transmission 59, the details of which will be described below, provides the desired gear reduction between motor 55 and rotor 56a. Output shaft 59b of transmission 59 is journaled in housing 46a by means of bearing 71. The shaft 59b is coupled to shaft 56b of rotor 56 by means of flexible coupling 60. This flexible coupling may be of any type which compensates for the reversing peak torque loads which are developed by the operation of valve 56 and applied to the shafts. Preferably coupling 60 is of the type which is commercially available under the trade name UNI/FLEX, sold by the Lovejoy Flexible Coupling Company, Chicago, Illinois. This coupling as shown in FIG. 3 is comprised of two hubs 61 joined together by means of individual layers of helically wound springs. This construction allows instantaneous relative angular displacement between the shafts thereby providing the compliance necessary to reduce the peak torque loads. The purpose of coupling 60 will be discussed in more detail in the description below the operation. Rotor 56a is secured on shaft 56b by a tapered bushing 72 and nut 73. This provides a positive connection between the shaft and the rotor so no slippage will occur. A seal means 74 is used to seal the interior of housing 46a

around shaft 56b. A stator 56c of valve 56 is fixed against rotation on housing 46a.

Transmission 59 is a heavy-duty, two-stage planetary gear reducer which can handle large loads in a relatively small volume within housing 46a. As shown in FIG. 5, input shaft 59a is journaled in transmission housing 80 by means of ball bearings 81. Sun gear 82 is formed integral on shaft 59a and cooperates with a plurality of planetary gears 83 which are rotatably mounted on first planet carrier 84. Integral with planet carrier 84 is intermediate shaft 85 which in turn has second sun gear 86 integral therewith. Sun gear 86 cooperates with a second plurality of planet gears 87 which are rotatably mounted on output planet carrier 88. Output planet carrier 88 is integral with output shaft 59b. Both sets of planetary gears 83, 87, respectively, cooperate with ring gear 89, as is well known in the transmission art. It can be seen by using a transmission such as disclosed in FIG. 5 that the speed of motor 55 can be greatly reduced in a very short overall length and still be rugged and transmit the loads from the motor to the rotor. All gears in transmission 59 are of high quality gear steel, surface hardened, and machined to precision tolerances to minimize backlash between the gears.

The operation of the invention is as follows. Logging-while-drilling tool 46 is positioned in drill collar 26 in drill string 24. Fluid circulating down the drill string will pass through slots 90 (FIG. 3) in rotor 56a and through slots 91 in stator 56c and on down through mud turbine 52 and out bit 27. As valve 56 continuously rotates between its open and closed positions, reverse loads occur on the valve. These reversing loads are applied through the shaft 56b to coupling member 60 which, due to its compliance, reduces the peak torques thus produced. Without coupling 60, these torques would be applied directly to transmission 59 to cause undue fatigue of the gears in the transmission. As the gears wear, the instantaneous angular velocity relationship between the motor 55 and rotor 56a degenerates and, accordingly, accurate signaling becomes difficult. The torque loads on shaft 56b, without coupling 60, also tend to fatigue the shaft itself and contribute to early failure thereof.

Also, looking at FIG. 4, it can be seen that when slots 92 and 91 are aligned, a piece of wood or the like entering the slots could jam the valve in an open position. If motor 55 were running through a direct drive into the valve 56, damage could occur to the motor. By use of clutch 58, this possibility of damage to motor 55 is eliminated in that, if valve 56 jams, the torque will build up on the clutch, release same, and allow the motor to run freely without any damage to the motor, gear train, etc.

What is claimed is:

1. A logging-while-drilling tool comprising:

- a housing adapted to be positioned in a drill string of an earth drilling apparatus wherein a drilling fluid which is circulated through the drill string will flow around said housing;
- a rotary valve positioned on said housing so that at least a portion of the drilling fluid flowing through

the drill string will flow through said valve, said valve having a shaft journaled in said housing;

a motor in said housing having a drive shaft and an operating characteristic determined by a downhole condition measured by said tool; and a drive train connecting said drive shaft of said motor to said shaft of said rotary valve, said drive train comprising:

a transmission having an input shaft and an output shaft;

first means connecting said drive shaft of said motor to said input shaft of said transmission; and

second means connecting said output shaft of said transmission to said shaft of said valve, said second means having means for reducing the reversing, opposed torque loads developed by operation of said rotary valve.

2. The logging-while-drilling tool of claim 1 wherein: said second means comprises a flexible coupling.

3. The logging-while-drilling tool of claim 1 wherein said first means comprises:

a clutch means which is engaged under normal operating conditions to form a positive driving connection between said drive shaft of said motor and said input shaft of said transmission but is automatically disengaged when rotation of one of said shafts is impaired to allow relative rotation between said shafts.

4. The logging-while-drilling tool of claim 3 wherein: said second means is a flexible coupling.

5. The logging-while-drilling tool of claim 4 wherein said flexible coupling comprises:

a first hub member affixed to said output shaft of said transmission;

a second hub member affixed to said shaft of said rotary valve; and

helically wound spring means connecting said first and second hub members together.

6. The logging-while-drilling tool of claim 5 wherein: said clutch means comprises a nonfriction, positive-cog clutch.

7. The logging-while-drilling tool of claim 6 wherein said transmission comprises:

a transmission housing;

said input shaft journaled in said housing;

a first sun gear on said input shaft;

a first planet carrier having a first plurality of planetary gears journaled thereon, said first planetary gears being driven by said first sun gear;

an output shaft on said first planet carrier;

a second sun gear on said first planet carrier output shaft;

a second planet carrier having a second plurality of planetary gears journaled thereon, said second planetary gears being driven by said second sun gear;

said output shaft of said transmission on said second planet carrier; and

ring gear means in said transmission housing for mating with said first and second planetary gears.

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