

[54] DATA-SIGNALING APPARATUS FOR WELL DRILLING TOOLS

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

[51] Int. Cl. G01n 1/14

[58] **Field of Search** 340/18 LD, 18 NC

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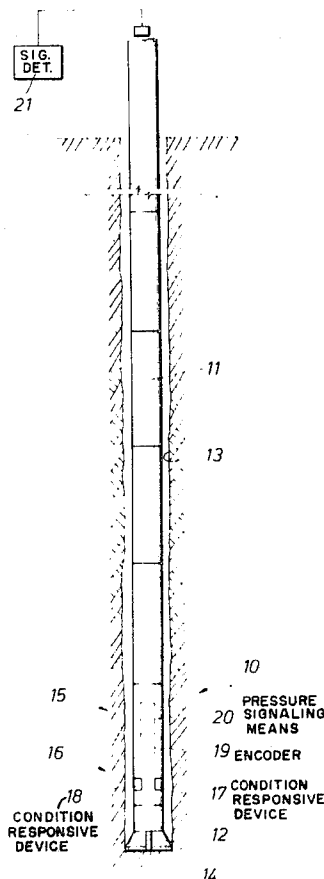
Assistant Examiner—N. Moskowitz

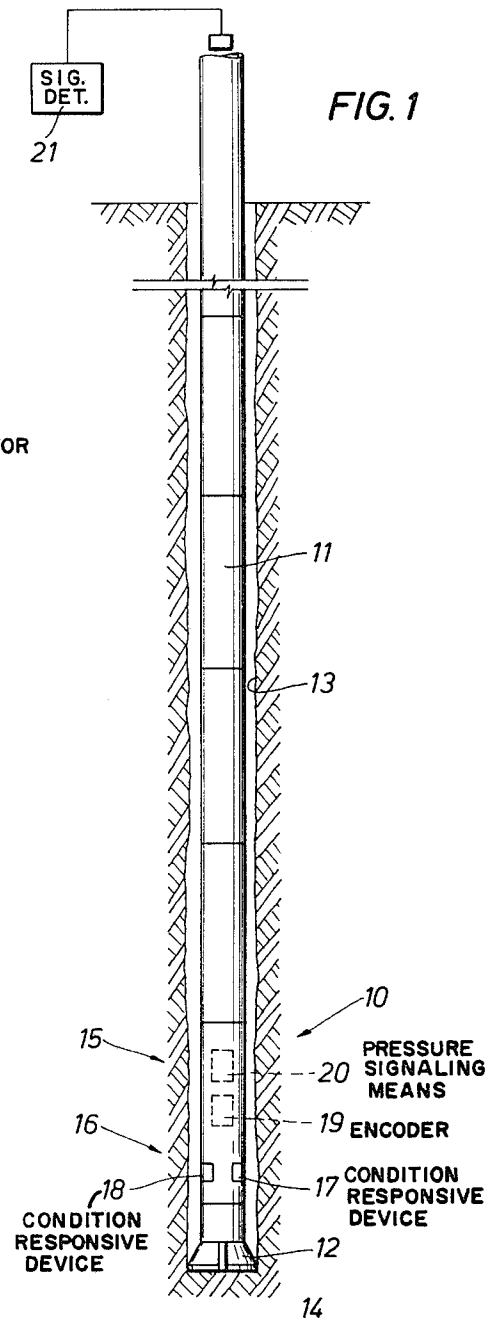
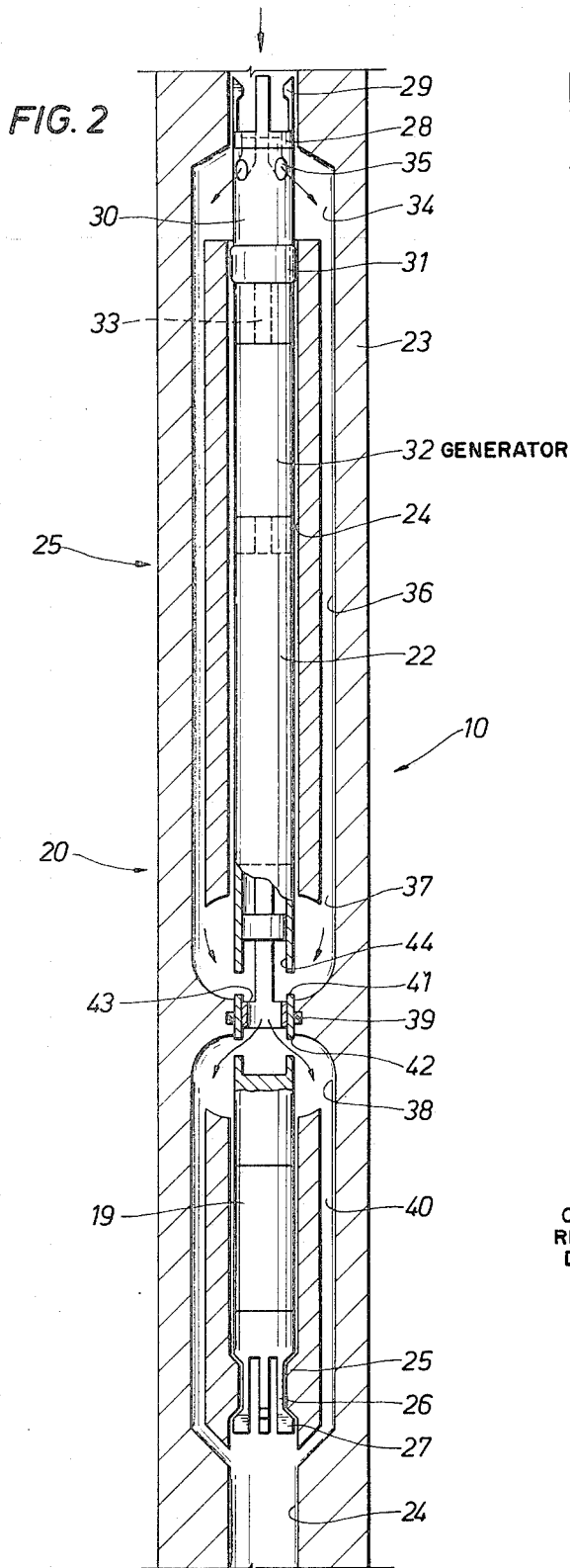
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[57] ABSTRACT

In the preferred embodiment of the invention disclosed herein, a well tool having new and improved data-signaling apparatus and carrying a drill bit on its lower end is dependently coupled with a drill string and lowered into a borehole being excavated. During the drilling operation, measurements are successively made of selected borehole conditions, formation properties, or the like, which are converted by the data-signaling apparatus into coded electrical signals for repetitively coupling a rotating shaft to a valve operatively arranged on the tool for selectively interrupting the flow of the drilling fluid being circulated through the drill string. In this manner, the valve is selectively reciprocated to produce a series of encoded pressure pulses in the drilling fluid which are representative of the measurements being obtained. These pressure pulses are transmitted through the drilling fluid to the surface where they are sensed and converted into meaningful indications of the measurements.

15 Claims, 9 Drawing Figures





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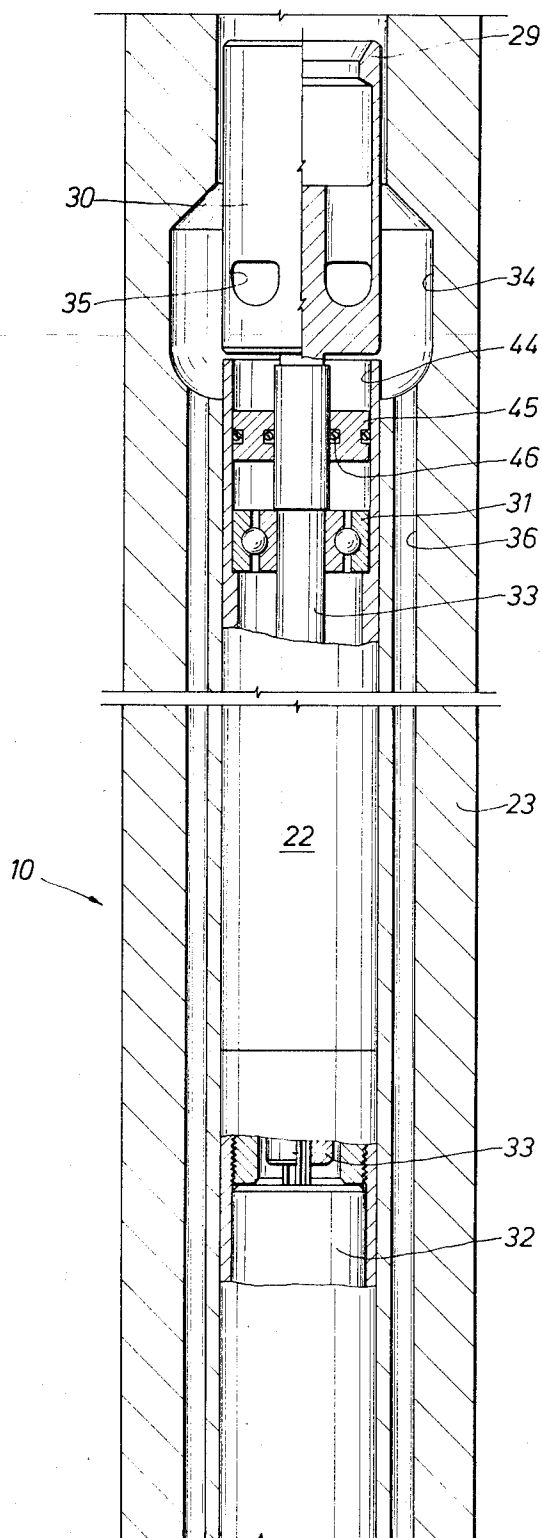


FIG. 3A

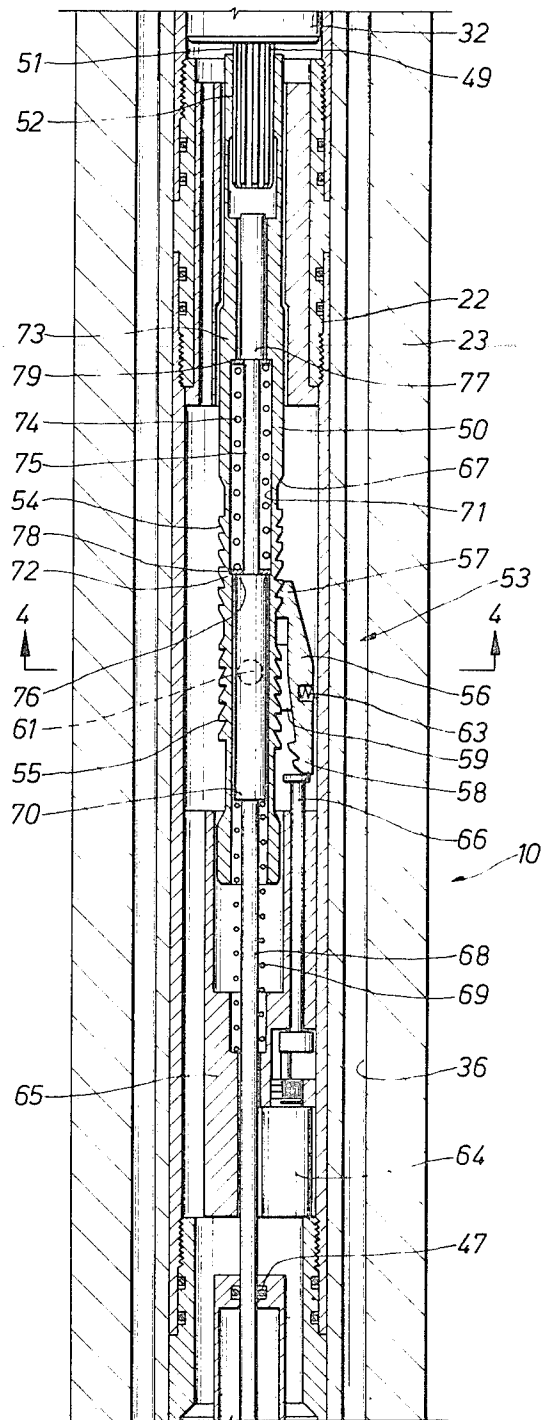


FIG. 3B

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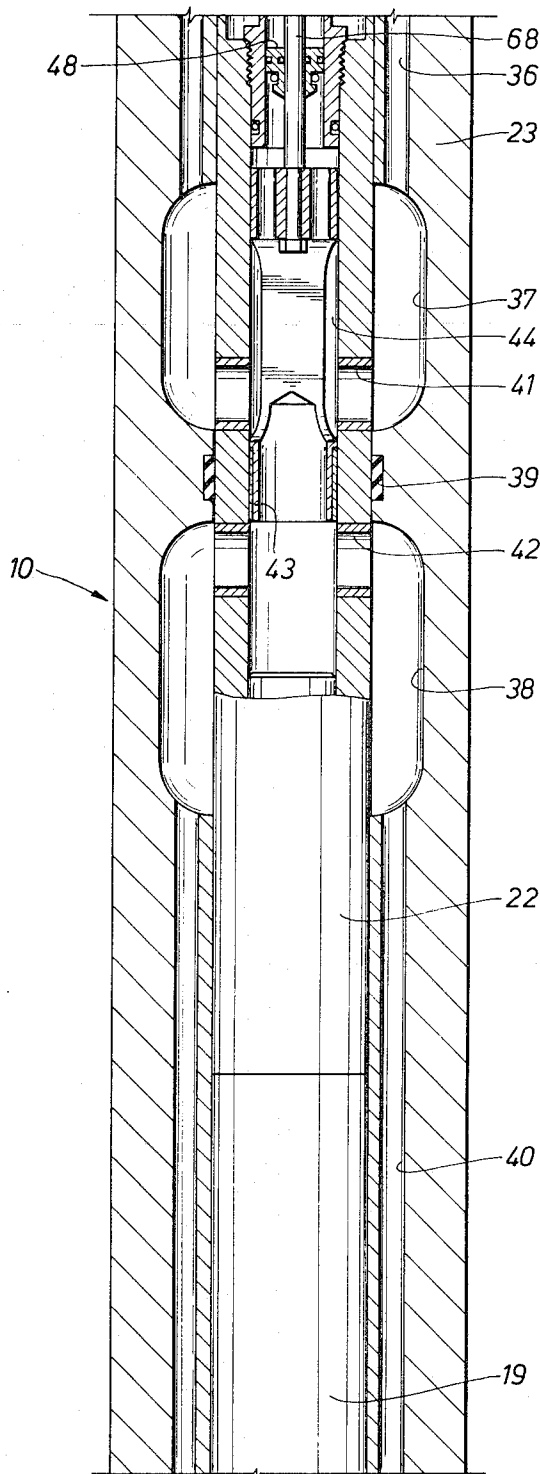


FIG. 3C

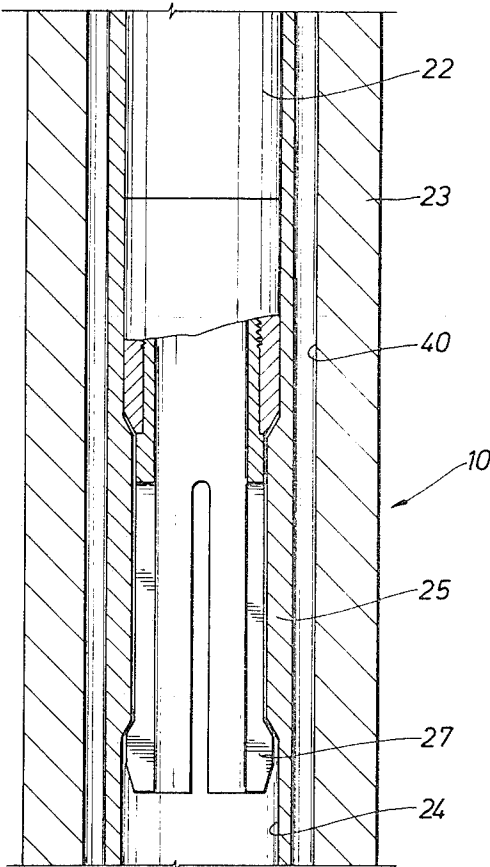


FIG. 3D

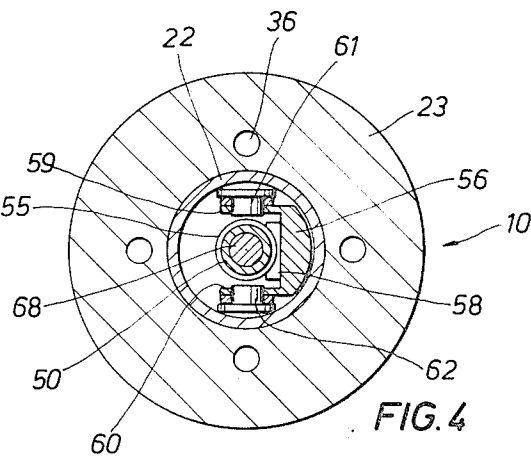


FIG. 4

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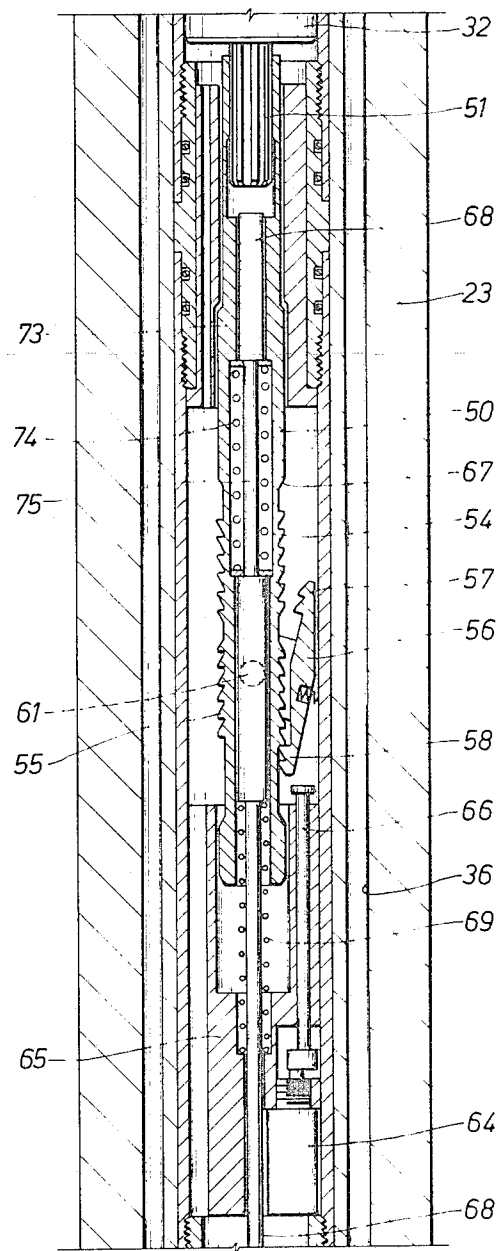
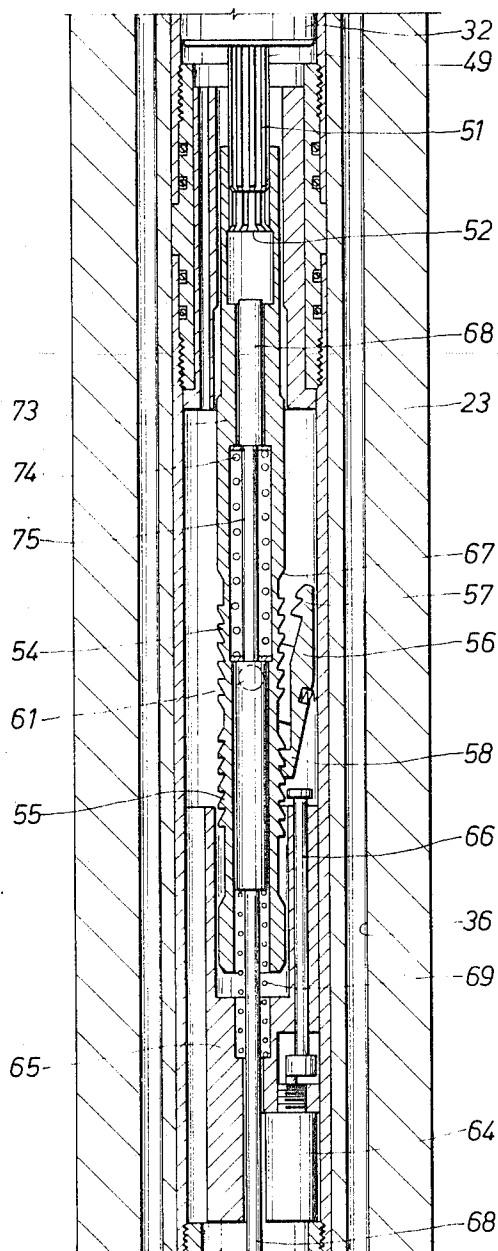


FIG. 6

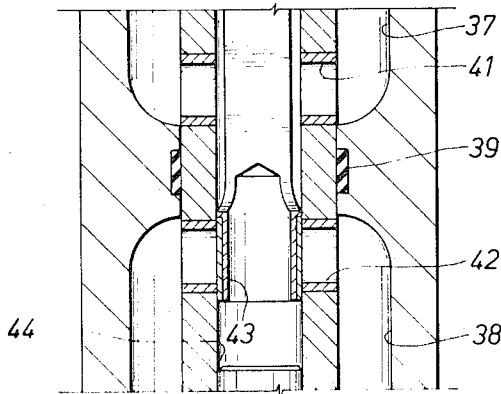


FIG. 5

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DATA-SIGNALING APPARATUS FOR WELL DRILLING TOOLS

Those skilled in the art have, of course, long recognized the benefits of obtaining various measurements at the bottom of a borehole during the course of a drilling operation. For instance, such information as the weight on the drill bit, the drill string torque, the inclination and the azimuthal direction of the borehole, bottom hole pressures and temperatures as well as various characteristics of the formations being penetrated are all measurements of significant interest.

Various proposals have, of course, been made heretofore for transmitting such measurements from the bottom of a borehole to the surface. Of the many different tools proposed, perhaps the most promising of all utilize a condition-responsive valve for selectively interrupting the flow of the circulating drilling fluid in a predetermined coded sequence representative of the measurements to produce a series of momentary pressure surges which are successively transmitted through the drilling fluid to the surface for detection by appropriate sensing devices. These proposed tools have, therefore, generally employed a typical solenoid-operated valve which is coupled to one or more condition sensing devices by means of appropriate electronic circuitry operatively arranged for opening and closing the valve in accordance with this sequence.

For various reasons, however, these prior proposals have generally been considered to be unacceptable for commercial drilling operations. For instance, since the signaling valves in such prior tools have customarily been directly operated by solenoids, the mechanical forces required just for operating these valves are so large that the power requirements for these solenoids become excessive in even relatively shallow wells. Moreover, by virtue of their substantial power requirements, the physical size of such solenoids make them impractical for the usual sizes of drilling tools.

Accordingly, it is an object of the present invention to provide new and improved data-signaling apparatus for use with well-drilling tools and which is specially adapted for rapidly transmitting downhole measurements to the surface with minimum electrical requirements.

This and other objects of the present invention are attained by providing a well tool adapted to be connected in a drill string having a drill bit dependently coupled thereto for excavating a borehole as a drilling fluid is circulated through the drill string and a fluid passage arranged in the tool. Data-signaling means are arranged on the tool and include condition-measuring means which are coupled to measurement-encoding means adapted for producing coded electrical signals indicative of one or more selected downhole conditions which may be experienced during the course of a drilling operation. To generate distinctive pressure pulses in the circulating drilling fluid representative of such measurements, the measurement-encoding means operatively drive pressure-signaling means arranged on the tool and including a rotatable shaft which is rotatively driven by the circulating fluid, a reciprocating valve member adapted to momentarily block or close the fluid passage for developing each pressure pulse, and valve-actuating means which are selectively operable to momentarily couple the shaft to the valve

member for moving the valve member to a passage-blocking position for developing a pressure pulse and then returning the valve member to a passage-opening position to await the next electrical signal. The pressure-signaling means further include an actuator which, in response to the electrical signals produced by the measurement-encoding means, merely initiates the operation of the valve-actuating means.

The novel features of the present invention are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may be best understood by way of the following description of exemplary apparatus employing the principles of the invention as illustrated in the accompanying drawings, in which:

FIG. 1 shows a well tool arranged in accordance with the present invention as it will appear while coupled in a drill string during the course of a typical drilling operation;

FIG. 2 schematically depicts a preferred embodiment of the well tool shown in FIG. 1;

FIGS. 3A-3D are successive elevational cross-sectional views of the well tool depicted in FIG. 2;

FIG. 4 is a cross-sectional view taken along the lines "4-4" in FIG. 3B; and

FIGS. 5 and 6 are elevational cross-sectional views showing the data-signaling apparatus of the tool illustrated in FIGS. 3A-3D to illustrate the operating cycle of the data-signaling apparatus.

Turning now to FIG. 1, a new and improved well tool 10 arranged in accordance with the present invention is depicted coupled in a typical drill string 11 having a rotary drill bit 12 dependently coupled thereto and adapted for excavating a borehole 13 through various earth formations as at 14. As the drill string 11 is rotated by a typical drilling rig (not shown) at the surface, substantial volumes of a drilling fluid or so-called "mud" are continuously pumped downwardly through the tubular drill string and discharged from the drill bit 12 to cool the bit as well as to carry earth borings removed by the bit to the surface as the mud is returned upwardly along the borehole 13 exterior of the drill string. As is typical, the mud stream is circulated by employing one or more high-pressure mud pumps (not shown) which continuously draw the fluid from a storage pit or vessel for subsequent recirculation by the mud pumps. It will be appreciated, therefore, that the constantly-circulating mud stream flowing through the drill string 11 serves as a transmission medium that is well suited for transmitting pressure surges or pulses to the surface.

In accordance with the principles of the present invention, data-signaling means 15 are arranged on the well tool 10 and include condition-measuring means 16 such as one or more condition-responsive devices, as at 17 and 18, which are coupled to an appropriate measurement encoder 19 operatively arranged to produce a series of coded electrical signals that are representative of the measurements being obtained by the condition-responsive devices. Pressure-signaling means 20 coupled to the encoder 19 are operatively arranged to respond to these coded signals for selectively generating a corresponding series of pressure pulses in the circulating fluid by momentarily and rapidly interrupting the flow of the drilling fluid through the drill string 11.

It will be appreciated, of course, that these transitory pressure pulses or surges will be similar to those caused by a so-called "water hammer." Thus, these pressure waves will be transmitted to the surface by way of the mud stream flowing within the drill string 11 and at the speed of sound in the particular drilling fluid. Accordingly, as will subsequently be explained in greater detail, the pressure-signaling means 20 produce these pressure pulses to provide encoded representations or data indicative of one or more downhole conditions sensed by the condition-measuring devices 17 and 18. This data is, in turn, successively transmitted to the surface in the form of these pressure pulses for detection and conversion into meaningful indications or records by suitable surface apparatus 21 such as the new and improved apparatus disclosed in either U.S. Pat. NO. 3,488,629 or U.S. Pat. NO. 3,555,504.

Turning now to FIG. 2, a schematic view is shown of the new and improved well tool 10 just prior to the production of a pressure surge or pulse which is to be transmitted to the surface by way of the drilling fluid being circulated through the drill string 11. As illustrated, the well tool 10 is comprised of an elongated tubular member 22 that is coaxially arranged within a thick-wall tubular housing 23 which is tandemly coupled in the drill string 11 just above the drill bit 12.

Although the inner tubular member 22 may just as well be permanently mounted in the housing 23, it is preferred to adapt the inner member for selective retrieval to the surface by way of the drill string 11. To facilitate this, the inner bore 24 of the tubular housing 23 is reduced to provide an annular shoulder 25 on which the lower end of the tubular member 22 is cooperatively seated and releasably latched to the housing by means such as one or more inwardly-contractible latch fingers 26 having outwardly-enlarged heads as at 27 which are dependently arranged on the inner member and adapted to contract as they pass through the annular shoulder and spring outwardly again to secure the inner member in its depicted position. Upright collet fingers 28 having inwardly-directed shoulders 29 are mounted on the upper end of the inner tubular member 22 and cooperatively arranged for receiving a conventional wireline grapple or overshot (not shown) adapted for being therewith to permit the inner member to be retrieved to the surface through the drill string 11.

To utilize the flowing mud steam as a motivating source for generating electrical power for operation of the new and improved data-signaling means 15, a reaction turbine 30 is journaled, as by a bearing 31, to the upper end of the inner member 22 and operatively arranged to be rotatively driven by the downwardly-flowing drilling fluid for driving a generator 32 coupled to the turbine by an elongated shaft 33. To facilitate the operation of the turbine 30, the inner bore 24 of the outer housing 23 is enlarged to provide an annular cavity or chamber 34 into which the mud stream will be discharged from the outlet ports 35 of the turbine. One or more longitudinal passages, as at 36, are formed in the outer housing 23 for conducting the mud stream from the upper chamber 34 to another chamber 37 formed therebelow in an intermediate portion of the outer housing. It will be appreciated, therefore, that during the operation of the well tool 10, the circulation

of the drilling fluid or mud will be effective for continuously driving the turbine 30 and the generator 32 coupled thereto to produce electrical power for operating the data-signaling means 15.

As depicted in FIG. 2, a second intermediate chamber 38 is formed in the outer housing immediately below the chamber 37 and the outer housing 23 is fluidly sealed in relation to the inner member 22 by a sealing member 39 mounted between the two intermediate chambers. One or more longitudinal passages, as at 40, are formed in the outer housing 23 and arranged for communicating the lower chamber 38 with the inner bore 24 of the outer housing below the shoulder 25. Lateral ports 41 and 42 are arranged at spaced intervals in the inner member 22 for respectively communicating the intermediate chambers 37 and 38 with the adjacent portion of the longitudinal bore 24 of the inner tubular member. To produce the aforementioned pressure pulses, the pressure-signaling means 20 include an annular valve member 43 which is slidably arranged in the longitudinal bore 44 of the inner member 22 and adapted for reciprocating movement therein between an elevated position (as depicted) between the fluid ports 41 and 42 and a lower port-closing position where the valve member is blocking the lower ports. It will be appreciated, of course, that by virtue of the annular configuration of the valve member 43, there will be no unbalanced longitudinally-acting pressure forces which would otherwise tend to retard the upward and downward movements of the valve member.

Accordingly, it will be recognized, that so long as the valve member 43 remains in its elevated position depicted in FIG. 2, the drilling fluid can freely circulate from the chamber 37 through the lateral ports 41 and 42 and pass without significant restriction into the chamber 38 and on through the fluid passages 40 and the longitudinal bore 24 to the drill bit 12 therebelow. On the other hand, it will be appreciated that downward movement of the valve member 43 to momentarily close the fluid ports 42 will produce a corresponding pressure surge or pulse which will be transmitted back up the mud stream in the drill string 11 for detection at the surface.

Turning now to FIGS. 3A-3D as well as FIG. 4, a preferred embodiment is depicted of the new and improved well tool 10 of the present invention with minor constructional details thereof being simplified or omitted to facilitate the explanation of the invention. As depicted in FIG. 3A, the reaction turbine 30 is arranged above the upper end of the inner member 22 and, as previously mentioned, operatively arranged for rotatively driving the shaft 33 and the generator 32 mounted therebelow. To protect the various moving elements of the well tool 10, the upper end of the inner member 22 is closed and fluidly sealed by an annular piston 45 which is slidably arranged within the longitudinal bore 44 of the inner member. A sealing member 46 carried by the piston 45 is suitably arranged for fluidly sealing the rotatable shaft 33. The internal bore 44 of the inner member 22 between the piston 45 and one or more fluid seals 47 and 48 above the valve member 43 is filled with a suitable oil so that the internal bore will be maintained at the hydrostatic pressure of the drilling fluid.

As shown in FIG. 3B, the generator shaft 49 is extended below the generator 32 and co-rotatively secured to a tubular shaft 50 by means such as one or more longitudinal splines 51 on the generator shaft which are slidably received within complementary spline grooves 52 arranged within the upper end of the tubular shaft for permitting the tubular shaft to slide longitudinally in relation to the generator shaft. Thus, as will subsequently be explained in greater detail, the tubular shaft 50 is cooperatively arranged for limited axial movement in relation to the generator shaft 49 but is co-rotatively secured thereto by means of the splines 51 and the grooves 52.

The pressure-signaling means 20 include valve-actuating means 53 adapted for utilizing the rotation of the turbine 30 to reciprocate the valve member 43. In the preferred manner of accomplishing this, opposite-handed threads 54 and 55 are arranged at spaced intervals along the tubular shaft 50. As illustrated in FIGS. 3B and 4, a pawl 56 having opposite-handed, inwardly-directed thread segments 57 and 58 at its upper and lower ends, respectively, is operatively arranged in an upright position within the internal bore 44 of the inner member 22 to position the thread segments adjacent to the threads 54 and 55 on the tubular shaft 50. To mount the pawl 56, a pair of inwardly-directed arms 59 and 60 are arranged on the mid-portion of the pawl and are pivotally coupled to the inner member 22 by a pair of transversely-oriented pivots 61 and 62 on opposite sides of the tubular shaft 50 so that the pawl can be tilted or rocked about the axis defined by the pivots. Biasing means, such as a laterally-oriented spring 63 between the inner member 22 and the back of the rocking pawl 56 at a point below the axis of the pivot pins 61 and 62, are operatively arranged for normally tilting the upper end of the pawl outwardly away from the tubular shaft 50.

To shift the pawl 56 to the position illustrated in FIG. 3B, the valve-actuating means 53 further include a solenoid 64 which is mounted within a body 65 secured to the inner member 22 and has a longitudinally-movable actuator 66 operatively arranged for movement upwardly into engagement with the lower end of the rocking pawl upon energization of the solenoid. Thus, as illustrated, when the solenoid 64 is energized, the actuator 66 will engage the lower end of the pawl 56 causing its lower end to tilt outwardly about the transverse axis of the pivots 61 and 62 thereby shifting the upper thread segments 57 inwardly into threading engagement with the upper threads 54 on the tubular shaft 50.

By making the upper threads 54 and the upper thread segments 57 right-handed, for example, it will be appreciated that when the pawl 56 is tilted to the position shown in FIG. 3B, clockwise rotation of the shafts 33 and 49 will be effective for progressively threading the tubular shaft downwardly along the upper thread segments and lowering it in relation to the generator shaft. A downwardly-directed inclined shoulder 67 is arranged around the tubular shaft 50 just above the upper threads 54 so that once the shoulder has been rotated under the upper thread segments 57, the upper end of the pawl 56 will, with the aid of the spring 63, be cammed laterally outwardly to disengage the upper thread segments from the upper threads. It will be appreciated that once the upper end of the pawl

56 is tilted outwardly, the spring 63 will retain the rocking pawl in that position to await the next actuation of the solenoid 64.

On the other hand, once the rocking pawl 56 is tilted outwardly, the lower thread segments 58 (which are preferably left-handed) will be shifted inwardly into engagement with the left-handed lower threads 55 on the tubular shaft 50. Thus, when the lower thread segments 58 are engaged with the lower threads 55, the continuous clockwise rotation of the shafts 33 and 49 will be effective for returning the tubular shaft upwardly in relation to the generator shaft. Accordingly, it will be appreciated that by virtue of the unique arrangement of the valve-actuating means 53, the continuous rotation of the shafts 33 and 49 will be effective for alternately raising and lowering the tubular shaft 50 in relation to the housing 23 according to the position of the rocking pawl 56 as determined by the selective operation of the solenoid 64.

It will, of course, be appreciated that the valve member 43 could be directly coupled to the reciprocating tubular shaft 50. A rigid connection between the shaft 50 and the valve member 43 could, however, result in damage to the valve-actuating means 53 should the valve member inadvertently become stuck as by debris becoming lodged between the valve member and the inner member 22. To avoid this, as best seen in FIGS. 3B and 3C, an elongated rod 68 slidably fitted within the tubular shaft 50 is extended downwardly through the internal bore 44 of the inner member 22 and the fluid seals 47 and 48 and coupled to the upper end of the annular valve member 43. As best illustrated in FIG. 3B, biasing means, such as a coil spring 69 coaxially arranged around the elongated rod 68 and engaged between the body 65 and a downwardly-directed shoulder 70 on the rod, are provided for normally urging the rod upwardly. The internal bore of the tubular shaft 50 is enlarged as at 71 to define therein opposed upwardly and downwardly-directed shoulders 72 and 73 and a coil spring 74 is coaxially fitted around a reduced portion 75 of the elongated rod 68 which also defines opposed upwardly and downwardly-directed shoulders 76 and 77 on the rod. A pair of washers 78 and 79 are engaged with the opposite ends of the spring 74 and slidably mounted around the reduced-diameter portion 75 of the elongated rod 68.

By cooperatively sizing the washers as illustrated, it will be seen that so long as the elongated rod 68 remains in the same longitudinal position in relation to the tubular shaft 50, the washers 78 and 79 will respectively straddle the lower shoulders 72 and 76 and the upper shoulders 73 and 77. Thus, upward and downward movements of the reciprocating tubular shaft 50 will be effective for moving the rod 68 and the valve member 43 upwardly and downwardly in unison with the shaft. On the other hand, should the valve member 43 become stuck, downward movements of tubular shaft 50 will not be unduly hampered since the shoulder 73 will engage the upper washer 79 and begin compressing the spring 74 to allow the tubular shaft to move freely downwardly in relation to the elongated rod 68. Conversely, should the valve member 43 become stuck in some position lower than that depicted in FIGS. 3B and 3C, upward movements of the

tubular shaft 50 in relation to the elongated rod 68 will similarly cause the lower washer 78 to be elevated above the shoulder 76 to again compress the spring 74. Accordingly, should the valve member 43 become stuck, the tubular shaft 50 will be free to reciprocate as well as rotate without undue interference. Moreover, by virtue of the cooperative arrangement of the spring 74 and the washers 78 and 79, the continued reciprocation of the tubular shaft 50 will successively subject the elongated rod 68 to alternate upward and downward impacts which will hopefully free the valve member 43 and allow it to again be repetitively opened and closed.

Turning now to the operation of the new and improved well tool 10. The solenoid 64 is initially unenergized so that the actuating rod 66 will initially be in its retracted position. When the solenoid 64 is unenergized, the rocking pawl 56 will, therefore, be tilted outwardly so as to disengage the upper thread segments 57 from the upper threads 54 on the tubular shaft 50. The lower thread segments 58 will be below the lower threads 55. Thus, as depicted in FIGS. 3B and 3C, with the valve member 43 in its elevated position the tubular shaft 50 will be free to rotate as the circulating drilling fluid continues to flow through the reaction turbine 30.

Once, however, an electrical signal is provided by the condition-measuring means 16 for energizing the solenoid 64, the actuator 66 will be shifted upwardly into engagement with the lower end of the rocking pawl 56. Thus, as shown in FIG. 3B, the rocking pawl 56 will be tilted inwardly so as to bring the upper thread segments 57 into engagement with the upper threads 54 on the tubular shaft 50. Once this is accomplished, continued rotation of the generator shaft 49 and the tubular shaft 50 will be effective for rotatively shifting the tubular shaft downwardly in rotation to the generator shaft.

By virtue of the coil spring 74 and the washers 78 and 79, the downward travel of the tubular shaft 50 will be effective for shifting the elongated rod 68 downwardly against the relatively-light coil spring 69 to move the annular valve member 43 from its open position as illustrated in FIG. 3C to its port-closing position as illustrated in FIG. 5. Simultaneously once the upper threads 54 have been threadedly driven below the upper thread segments 57, the downwardly-directed shoulder 67 will be effective for camming the upper end of the rocking pawl 56 outwardly to cooperatively engage the lower thread segments 58 with the upper portion of the lower threads 55. Thus, the continued rotation of the tubular shaft 50 will be effective for quickly returning the tubular shaft upwardly in relation to the generator shaft 49. Upward movement of the tubular shaft 50 will, of course, be effective for returning the elongated rod 68 upwardly to restore the valve member 43 to its elevated position.

As best seen in FIG. 6, once the lower threads have moved upwardly out of threaded engagement with the lower thread segments, further reciprocating movements of the tubular shaft 50 will cease inasmuch as neither of the thread segments 57 or 58 are in engagement with the upper or the lower threads 54 and 55. Thus, so long as the solenoid 64 remains unenergized the actuating rod 66 will remain in the retracted position illustrated in FIG. 6 and the continued rotation of the generator shaft 49 and the tubular shaft 50 will be ineffective for operating the valve member 43. It will,

of course, be appreciated that energization of the solenoid 64 will be effective for again tilting the upper portion of the rocking pawl 56 inwardly so as to coengage the upper thread segments 57 with the upper threads 54 as shown in FIG. 3B. To assure that the shaft 49 and 50 will continue to rotate while the valve member 43 is momentarily closed, it is preferred that the rotating portion of the generator 22 include a flywheel (not shown). It will also be recognized that a suitable bypass can be arranged around the ports 41 and 42 so that a limited quantity of drilling fluid will continue to flow for driving the turbine 30 when the valve member is momentarily in its port-closing position.

Accordingly, it will be appreciated that the new and improved data-signaling means of the present invention are particularly suited for rapidly transmitting downhole measurements to the surface. By arranging the valve-actuating means in accordance with the principles of the present invention, the circulation of the drilling fluid through the well tool will be momentarily halted or slowed to produce each pressure signal without requiring the use of a large or slow-moving solenoid actuator for operating the valve controlling the fluid circulation.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. Apparatus adapted for transmitting data to the surface during the drilling of a borehole and comprising: a body adapted for connection in a tubular drill string and having a flow passage arranged to carry drilling fluids between the surface and a borehole-drilling device dependently coupled therebelow; pressure-signaling means on said body and including valve means adapted for reciprocating movement between passage-opening and passage-obstructing positions to regulate the flow of drilling fluids through said flow passage and produce pressure pulses in such fluids for transmission therethrough to the surface; a fluid turbine operatively arranged in said flow passage and adapted to be rotatively driven by drilling fluids flowing through said flow passage; motion-converting means operatively arranged between said fluid turbine and said valve means and adapted for selectively reciprocating said valve means between said positions upon rotation of said fluid turbine, said motion-converting means including a first shaft coupled to said fluid turbine and adapted to be rotatively driven thereby in a selected rotative direction, a second shaft coupled to said valve means and adapted to impart reciprocating movement thereto, means corotatively securing said shafts to one another and adapted for enabling said second shaft to reciprocate axially in relation to said first shaft, and first and second sets of oppositely-handed threads arranged along said second shaft; and actuating means responsive to electrical signals operatively associated with said motion-converting means and adapted for selectively actuating said motion-converting means to reciprocate said valve means, said actuating means including threaded means

movably mounted on said body and having first and second oppositelyhanded complemental threads respectively adapted for selective movement into and out of engagement with said first and second sets of threads on said second shaft, said first threads being cooperatively arranged so that upon threaded engagement with one another rotation of said shaft in said rotative direction will move said second shaft in one axial direction in relation to said first shaft, said second threads being cooperatively arranged so that upon threaded engagement with one another rotation of said shafts in said rotative direction will move said second shaft in the other axial direction in relation to said first shaft, and electrical means responsive to said electrical signals adapted for selectively moving said threaded means at least into engagement with said second shaft.

2. The apparatus of claim 1 further including electrical signaling means on said body coupled to said electrical means and adapted for producing electrical signals representative of at least one downhole condition to repetitively operate said electrical means.

3. The apparatus of claim 2 further including an electrical generator coupled to said fluid turbine and adapted for supplying electrical power to said electrical signaling means.

4. The apparatus of claim 1 wherein said first and second shafts are in coincidental alignment with one another.

5. The apparatus of claim 1 wherein said first and second shafts are in coincidental alignment with one another and are extended longitudinally in relation to said body.

6. The apparatus of claim 1 wherein said threaded means include a pawl member movably mounted on said body adjacent to said first and second sets of threads and having said first and second complemental threads arranged thereon to be alternately engaged with said first and second sets of threads respectively upon movement of said pawl member to first and second positions; and said electrical means include a solenoid actuator operatively associated with said pawl member and adapted, upon energization, to move said pawl member to at least one of its said positions.

7. The apparatus of claim 6 further including cam means operatively arranged on said second shaft and adapted for moving said pawl member from its said one position to its other position upon axial movement of said second shaft carrying one of said sets of threads out of threaded engagement with its associated complemental threads on said pawl member.

8. Apparatus adapted for determining at least one downhole condition while drilling a borehole and comprising: a body tandemly coupled in a tubular drill string having a borehole-drilling device dependently coupled thereto and defining a flow passage for circulating drilling fluids between the surface and said borehole-drilling device; data-signaling means on said body adapted for producing electrical signals indicative of at least one downhole condition; pressure-signaling means on said body adapted for developing pressure pulses in drilling fluids flowing through said drill string for transmission to the surface and including a valve member adapted for reciprocating movement between an inactive position and an active position obstructing said flow passage to produce said pressure pulses; a

fluid turbine operatively arranged in said flow passage and adapted to be rotatively driven by drilling fluids therethrough; and motion-converting means responsive to said electrical signals operatively arranged between said valve member and said fluid turbine and adapted upon rotation thereof for selectively reciprocating said valve member between its said positions each time said data-signaling means produce an electrical signal, said motion-converting means including a shaft coupled to said valve member, means corotatively coupling said shaft to said fluid turbine without preventing axial reciprocating movement of said shaft in relation thereto, a set of threads arranged along said shaft, a pawl member movably mounted on said body adjacent to said shaft and having complemental threads arranged thereon and adapted for coengagement with said shaft threads upon movement of said pawl member toward said shaft so that rotation of said shaft by said fluid turbine will shift said shaft in one axial direction as said shaft threads are threaded along said pawl threads, means operative upon engagement of said shaft threads from said pawl threads for returning said shaft in the opposite axial direction to again reposition said shaft threads adjacent to said pawl threads, and electrical means cooperatively associated with said pawl member and adapted for selectively moving said pawl member toward said shaft each time said data-signaling means produce an electrical signal.

9. The apparatus of claim 8 wherein said shaft is tubular; and further including a second shaft coaxially disposed in said tubular shaft and secured to said valve member, and means yieldably coupling said second shaft to said tubular shaft for permitting axial movement of said tubular shaft in relation to said second shaft.

10. The apparatus of claim 8 further including means adapted to be located at the surface and responsive to said pressure pulses for providing indications of said pressure pulses.

11. The apparatus of claim 8 further including an electrical generator coupled to said fluid turbine and adapted for supplying power to said motion-converting means for operation thereof.

12. Apparatus adapted for determining at least one downhole condition while drilling a borehole and comprising: a body tandemly coupled in a tubular drill string having a borehole-drilling device dependently coupled thereto and defining a flow passage for circulating drilling fluids between the surface and said borehole-drilling device; data-signaling means on said body adapted for producing electrical signals indicative of at least one downhole condition; pressure-signaling means on said body adapted for developing pressure pulses in drilling fluids flowing through said drill string for transmission to the surface and including a valve member adapted for reciprocating movement between an inactive position and an active position obstructing said flow passage to produce said pressure pulses; a fluid turbine operatively arranged in said flow passage and adapted to be rotatively driven by drilling fluids flowing therethrough; and motion-converting means responsive to said electrical signals operatively arranged between said valve member and said fluid turbine and adapted upon rotation thereof for selectively reciprocating said valve member between its said posi-

11

tions each time said data-signaling means produce an electrical signal, said motion-converting means including a shaft coupled to said valve member, means corotatively coupling said shaft to said fluid turbine without preventing axial reciprocating movement of said shaft in relation thereto, first and second sets of oppositely-handed threads arranged along said shaft, a pawl member movably mounted on said body adjacent to said shaft and having first and second sets of complementary oppositely-handed threads arranged thereon respectively adapted to be alternately coengaged with said first and second shaft threads upon alternate movements of said pawl member toward said shaft so that rotation of said shaft by said fluid turbine will shift said shaft in one axial direction as said first shaft threads are threaded along said first pawl threads and shift said shaft in the opposite axial direction as said second shaft threads are threaded along said second pawl threads, means operative upon disengagement, of said first shaft threads from said first pawl threads for moving said pawl member to engage said second pawl threads with said second shaft threads, and electrical

12

means cooperatively associated with said pawl member and adapted for selectively moving said pawl member toward said shaft to coengage said first threads each time said data-signaling means produce an electrical signal.

13. The apparatus of claim 12 wherein said shaft is tubular; and further including a second shaft coaxially disposed in said tubular shaft and secured to said valve member, and means yieldably coupling said second shaft to said tubular shaft for permitting axial movement of said tubular shaft in relation to said second shaft.

14. The apparatus of claim 12 further including means adapted to be located at the surface and responsive to said pressure pulses for providing indications of said pressure pulses.

15. The apparatus of claim 12 further including an electrical generator coupled to said fluid turbine and adapted for supplying power to said motion-converting means for operation thereof.

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