

- [54] METHOD AND APPARATUS FOR CONTROLLING THE DOWNHOLE ACOUSTIC TRANSMITTER OF A LOGGING-WHILE-DRILLING SYSTEM**

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- [52] U.S. Cl.... 340/18 NCS, 340/18 LD, 200/61.46,  
322/32, 317/5

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

- [58] **Field of Search**..... 340/18 NC, 18; 200/61.46;  
322/12, 32; 317/5

- [56]
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- [57]
- ABSTRACT**

A logging-while-drilling system utilizes the flow of drilling fluid within a borehole as the transmission medium for telemetering downhole logging measurements to the earth's surface. The hydraulic power within the drilling fluid is converted to suitable power for driving a downhole acoustic transmitter which produces an acoustic wave within the drilling fluid which is modulated with the information describing the downhole logging conditions. The power available for driving the transmitter is applied to the transmitter when it exceeds the minimum starting power requirement of the transmitter and is continuously applied to the transmitter so long as it does not, after starting the transmitter, drop below the minimum operating power requirement of the transmitter.

### 4 Claims, 5 Drawing Figures

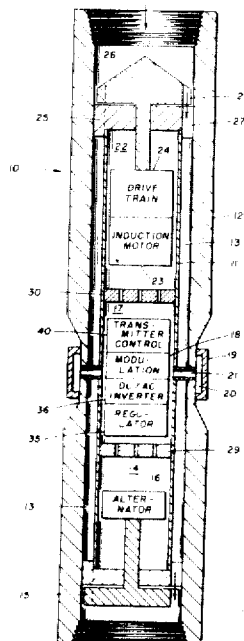
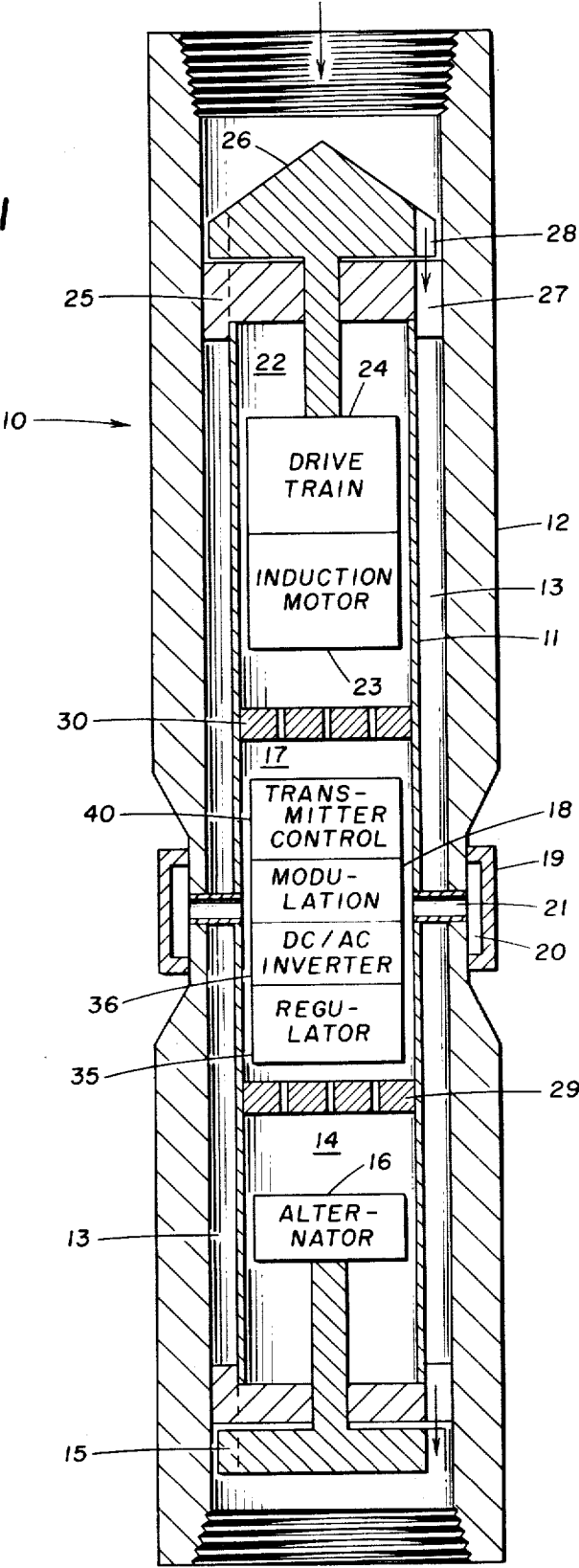


FIG. 1



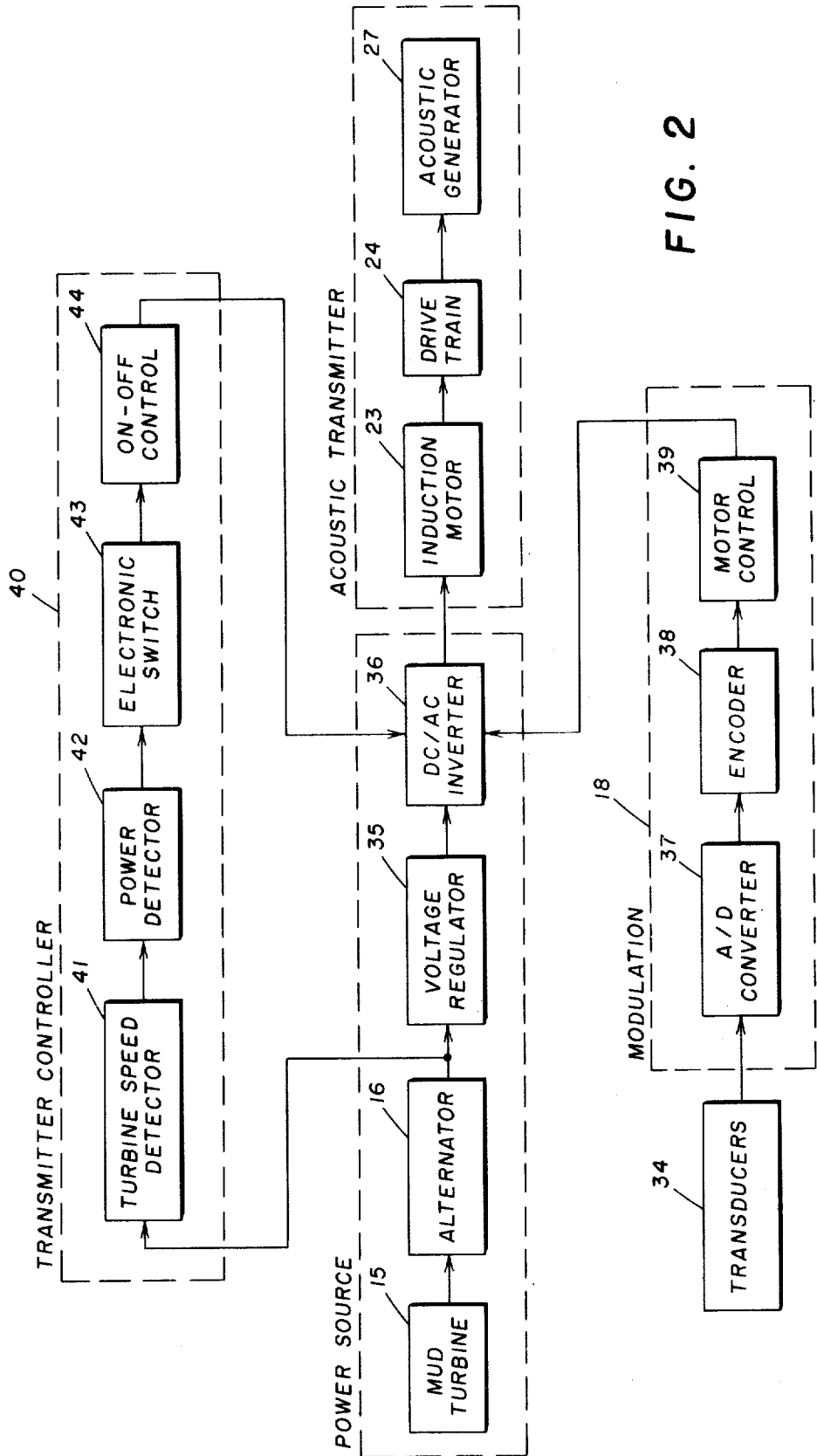


FIG. 2

FIG. 3

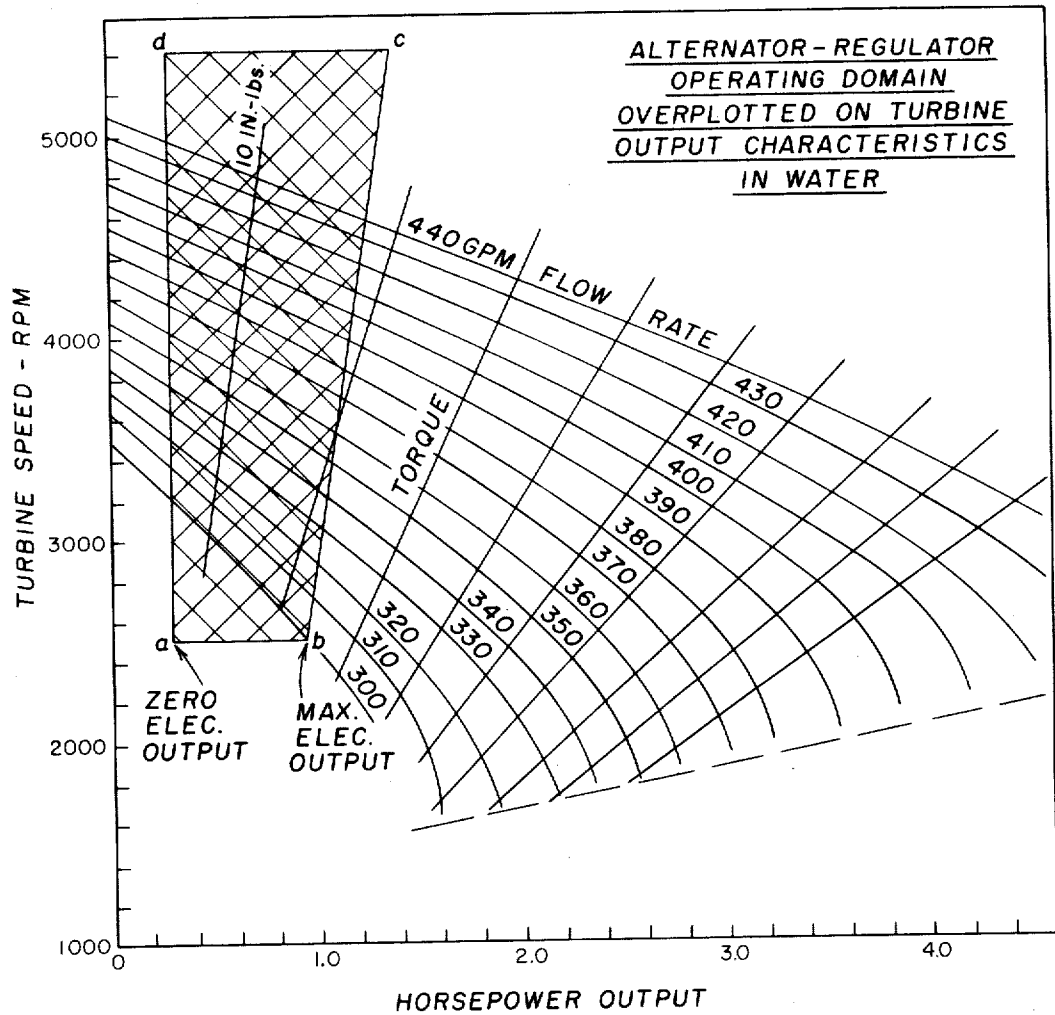


**FIG. 4**

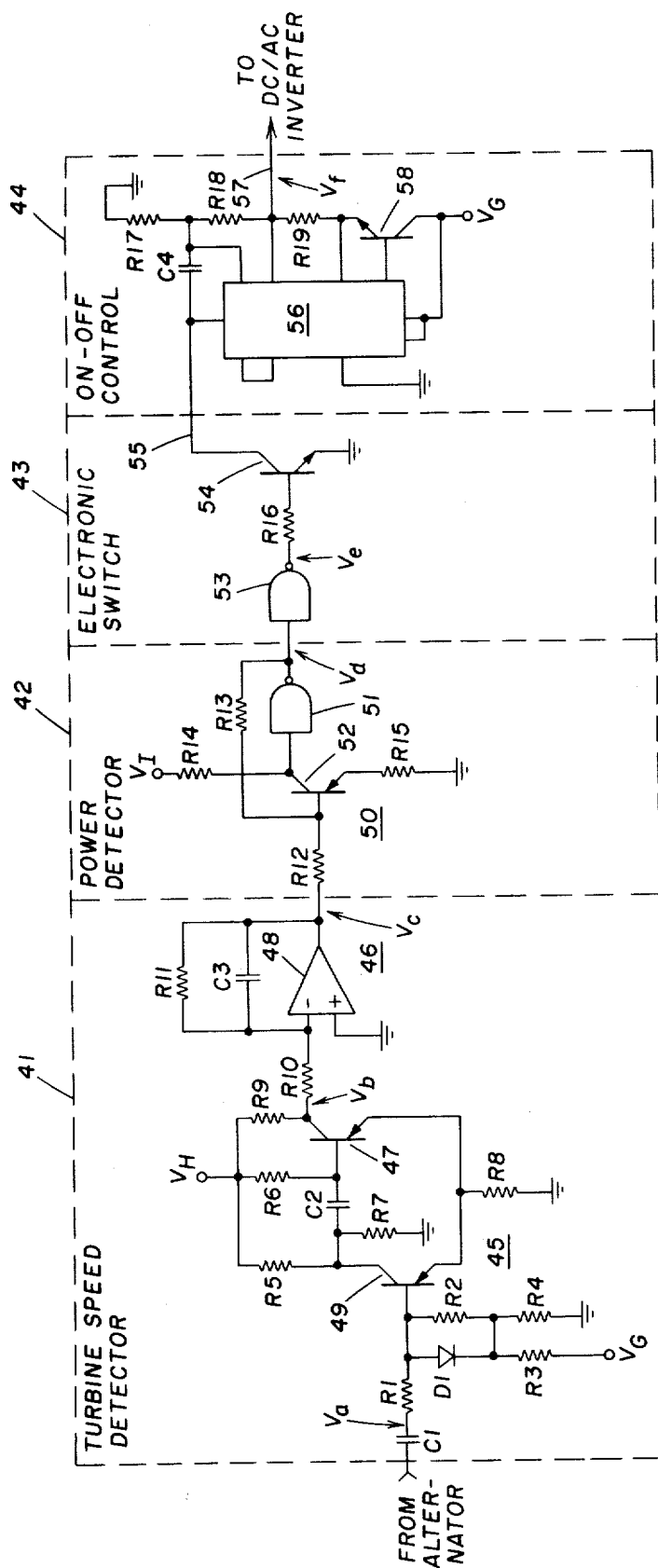
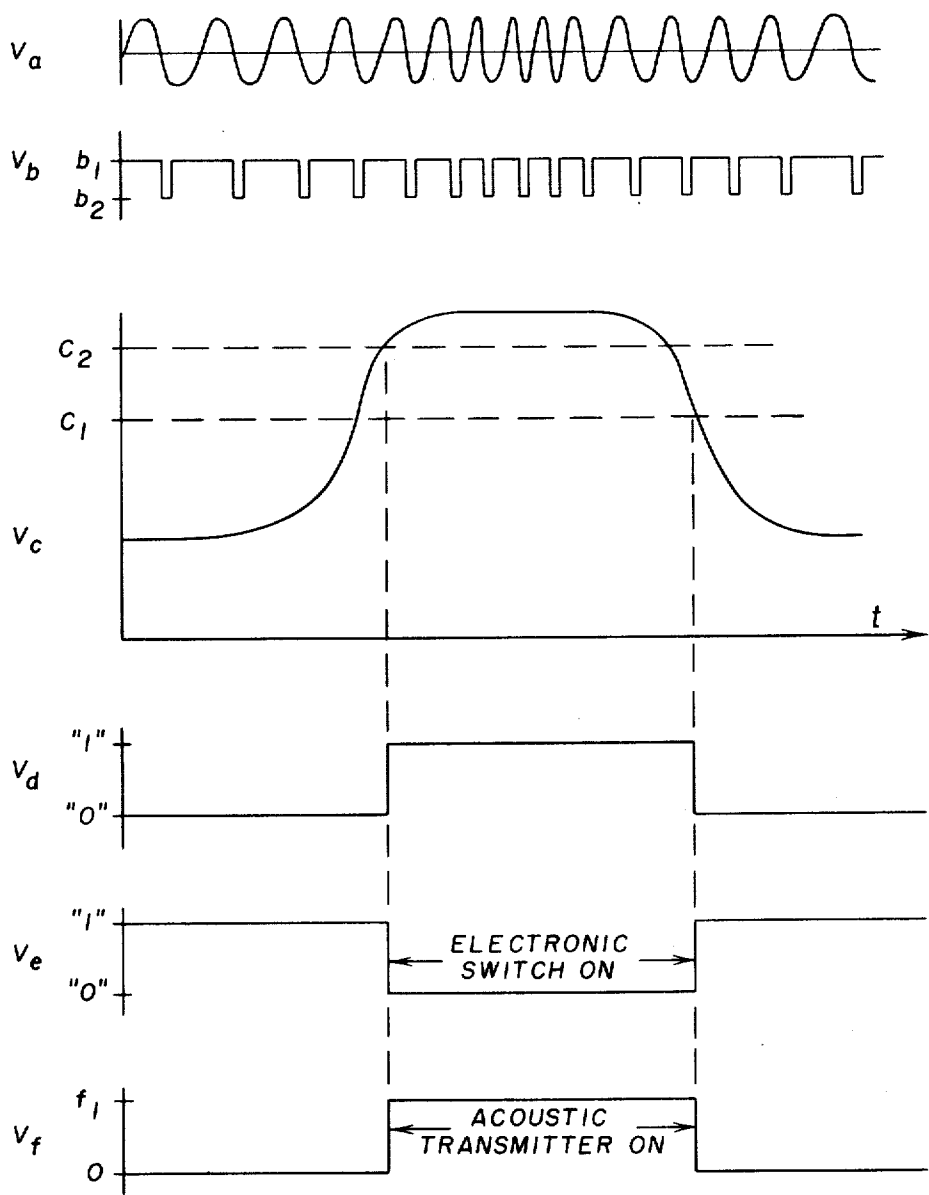


FIG. 5



# METHOD AND APPARATUS FOR CONTROLLING THE DOWNHOLE ACOUSTIC TRANSMITTER OF A LOGGING-WHILE-DRILLING SYSTEM

## BACKGROUND OF THE INVENTION

This invention relates generally to the continuous logging of downhole conditions within a borehole. More particularly, it relates to logging while drilling wherein measurements of downhole conditions within a borehole are telemetered to the surface of the earth by means of a continuous acoustic wave passing upward through the drilling fluid.

In the past, a conventional practice in the logging of a borehole has been to apply electric current from a suitable source aboveground through an insulated conductor extending into the borehole to sensing apparatus. The sensing apparatus provides a signal in the insulated conductor representative of the characteristic measured within the borehole. The provision and maintenance of such an insulated conductor for logging the borehole while simultaneously drilling the borehole has been found to be impractical.

More recently, logging-while-drilling systems have been employed which do not require an insulated conductor in the borehole at any time for logging operations. In one such system, the sensing apparatus located within the borehole transmits the logging measurements by means of an acoustic wave passing upward through the drill string. An example of such a system is disclosed in U.S. Pat. No. 2,810,546 to B. G. Eaton et al. In another such system the drilling liquid within the borehole is utilized as the transmission medium for the information-bearing acoustic waves. An example of such a system is disclosed in U.S. Pat. No. 3,309,656 to John K. Godbey. In the Godbey system, drilling fluid is continuously circulated downward through the drill string and drill bit and upward through the annulus provided by the drill string and the borehole wall, primarily for the purpose of removing cuttings from the borehole. An acoustic transmitter located downhole continuously interrupts the flow of the drilling fluid, thereby generating an acoustic wave in the drilling fluid. The acoustic wave is modulated with information measured downhole by sensing apparatus, and the modulated acoustic wave is telemetered uphole through the drilling fluid to suitable recording equipment.

## SUMMARY OF THE INVENTION

In accordance with one aspect of the invention the hydraulic power in the drilling fluid which is being circulated through the borehole is converted at a downhole location into electrical power. This electrical power is utilized to generate a continuous acoustic wave in the drilling fluid upon the electrical power exceeding a first power level. The acoustic wave is maintained continuously so long as the electrical power, after initially exceeding the first power level, does not drop below a second power level. The acoustic wave is modulated in response to a measured downhole condition, the modulated acoustic wave passing upward through the drilling fluid to the surface of the earth where it is demodulated to provide a readout of the measured conditions.

In a further aspect, the electrical power drives an acoustic transmitter which periodically interrupts the flow of drilling fluid to produce the continuous acoustic

wave. The electrical power which is derived from the hydraulic power in the drilling fluid is continuously monitored and is connected to the acoustic transmitter only after it exceeds the starting power requirement of the acoustic transmitter and is disconnected from the acoustic transmitter when, after the transmitter is started, it drops below the operating power required to maintain continuous operation of the acoustic transmitter.

More particularly, a rotary-driven member is responsive to the hydraulic power in the drilling fluid for generating mechanical power. The mechanical power is converted into an alternating-frequency electrical power, the frequency of the electrical power being proportional to the speed of the rotary-driven member and therefore proportional to the power available for driving the acoustic transmitter. The frequency of the electrical power is continuously detected. The electrical power is connected to the acoustic transmitter to start-up the acoustic transmitter when the detected frequency indicates that the speed of the rotary-driven member exceeds the speed required to produce the mechanical power sufficient for generating the electrical power required to overcome the start-up load condition of the acoustic transmitter. If, after start-up of the acoustic transmitter, the detected frequency indicates that the speed of the rotary-driven member has dropped below the speed required to produce sufficient mechanical and electrical power to maintain continuous and nonerratic operation of the acoustic transmitter, the electrical power is disconnected from the acoustic transmitter to shut-down the acoustic transmitter.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a borehole logging tool utilized in a logging-while-drilling system.

FIG. 2 is a flow diagram illustrating the components housed within the borehole logging tool of FIG. 1.

FIG. 3 is a plot of the operating characteristics of one of the components of FIG. 2.

FIG. 4 is a detailed electrical schematic of the transmitter controller of the present invention.

FIG. 5 illustrates the waveforms of the signals appearing at the designated points in the electrical schematic of FIG. 4.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with the present invention a transmitter controller is provided for controlling the start-up and shut-down of the downhole acoustic transmitter in a logging-while-drilling system. The transmitter controller turns the acoustic transmitter ON only after the speed of the mud turbine has exceeded the minimum speed required to generate maximum starting power for the acoustic transmitter. Any time the turbine speed drops below the minimum speed required to generate nominal operating power for the acoustic transmitter, transmitter controller turns the acoustic transmitter OFF. The transmitter controller of the present invention is particularly suitable for inclusion in a logging-while-drilling system utilizing conventional rotary drilling apparatus.

A brief description of a conventional rotary drilling apparatus with which this invention can be used will be given prior to the detailed description of the invention

itself. In FIG. 1 there is shown a downhole logging tool 10 formed by an inner housing 11 located within an outer housing 12. The inner and outer housings define an annulus 13 through which drilling mud passes during drilling operations. The upper and lower ends of the outer housing 12 are threaded for connection into a drill string. Within the inner housing 11 are contained the operating parts of the logging-while-drilling system, the power source, the modulation section, the acoustic transmitter, and the transmitter controller.

The power requirements for the acoustic transmitter are derived from a power source comprising the mud turbine 15, the alternator 16, the voltage regulator 35, and the DC/AC inverter 36. The mud turbine 15 is located immediately below the lower section 14, and the alternator 16 is located within the lower section 14. During the drilling operations, drilling fluid, preferably "mud," is continuously circulated through the drill bit by a positive displacement pump located aboveground, primarily to remove cuttings from the hole. There is substantial hydraulic power in this drilling mud. In the logging-while-drilling system, this drilling mud is passed through the annulus 12, and the hydraulic power is converted to mechanical power by means of the mud turbine 15. Mud turbine 15 drives the alternator 16 to convert the mechanical power to AC electrical power. Located within a middle section 17 is the voltage regulator 35 which rectifies and filters the AC power output from the alternator 16 and provides a regulated DC power output. The DC/AC inverter 36 converts the DC power into suitable AC power for starting and operating the acoustic transmitter. The middle section 17 is sealed from the lower section 14 by means of bulkhead 29. The electrical connection from the alternator 16 to the voltage regulator 35 passes through this bulkhead.

Also located near and in communication with middle section 17 are the various types of transducers used to convert such downhole conditions as fluid pressures and temperatures, drilling conditions and parameters, and formation characters into analog electrical signals. These analog signals are applied to the modulation section 18 for conversion into digital signals for use in modulating the acoustic transmitter. The collar 19 surrounding the outer housing 12 provides a compartment 20 within which the transducers may be located. The transducers communicate with the modulation section 18 by means of the channel 21 leading from compartment 20 into the middle section 17.

Located within an upper section 22 is an induction motor 23 and a drive train 24. An acoustic generator comprising a fixed stator 25 and a rotary valve 26 is located immediately above the upper section 22. These four components, induction motor 23, drive train 24, stator 25, and rotary valve 26, comprise the acoustic transmitter. Rotary motion of the rotary valve 26 is initiated and maintained by the induction motor 23 which is connected rigidly to the rotating valve through the drive train 24. The induction motor 23 is electrically connected to the DC/AC inverter 36 through the bulkhead 30 which seals the middle section 17 from the upper section 22. The stator 25 and the rotary valve 26 have complementing slots 27 and 28. The rotor is in an open position when the slot 28 is rotated to a position which is in communication with the slot 27 of the stator 25. In this open position, the drilling mud will pass through the slots in the rotor and stator and through the annulus 13 to drive the turbine 15. The hydraulic

power in the drilling mud is converted by the turbine 15 to mechanical power which in turn is converted to electrical power for rotating the rotary valve 26. As the valve 26 is rotated, it continuously interrupts the flow of mud, thereby generating the acoustic signal which travels upward through the mud column to the surface of the earth.

This acoustic signal may be modulated with the digital signals which represent the downhole condition measurements from the transducers. These digital signals are utilized within the modulation section 18 to control the frequency of the AC power applied to the induction motor 23 and, consequently, the speed of the induction motor 23. As it is the speed of the induction motor which determines the frequency of the acoustic signal, the acoustic signal is therefore frequency modulated in response to the digital signals representing the downhole conditions measured by the logging transducers. In this manner, modulated, continuous, acoustic waves travel uphole in the drilling mud and are received at the earth's surface and demodulated to provide a readout of the downhole conditions.

Referring now to FIG. 2, there is illustrated in flow diagram the details of the borehole logging tool illustrated in FIG. 1. As previously described, the mud turbine 15 converts the hydraulic power in the drilling mud to mechanical power for driving the alternator 16 which, preferably, is a three-phase, six-pole alternator. The three-phase, AC power from the alternator 16 is applied to a voltage regulator 35 which rectifies and filters the AC power output from the alternator and provides a regulated DC voltage output. This regulated DC voltage is converted by a DC/AC inverter 36 into suitable AC power for starting and operating the induction motor 23 in the acoustic transmitter.

The downhole measurements of the transducers 34, in analog form, are coded into binary digital words by an A/D converter 37. Each digital word is converted into serial binary bits by an encoder 38 and applied to motor control 39 which in turn regulates the frequency of the AC power applied from the DC/AC inverter 36 to the induction motor 23, consequently varying the speed of the induction motor 36 and thereby modulating the acoustic signal output from the acoustic generator 27 in accordance with the digital information applied to the motor control circuit 39.

An example of the type of borehole logging tool illustrated in FIG. 1 and discussed so far in relationship to FIG. 2 is set forth in U.S. Pat. No. 3,309,656 to John K. Godbey. For a more detailed description of the mechanical and electrical features of such a borehole logging tool, reference may be had to the aforementioned patent to Godbey. In addition to the circuitry illustrated and described so far with relationship to FIG. 2, there is also illustrated the transmitter controller portion 40 which comprises the present invention. Transmitter controller 40 comprises a turbine speed detector 41, a power detector 42, and electronic switch 43, and an ON-OFF control 44. Prior to describing the operation of the transmitter controller 40, there will be described the operating characteristics of the mud turbine 15 utilized in the logging-while-drilling system to which the operation of the transmitter controller 40 is directed.

Such characteristics of the mud turbine are illustrated in FIG. 3 wherein turbine speed is plotted versus power output for constant mud flow rates. Curves are

shown for mud flow rates between 300 and 400 gallons per minute (gpm). These curves show the speed regulation characteristics of the mud turbine 15 with load and flow rate. The alternator 16/regulator 35 operating domain is shown superimposed on the turbine characteristics as the enclosed area *a, b, c, d*. As the AC power is initially applied to the acoustic transmitter during transmitter start-up, a start-up load is presented to the power source. This start-up load causes the mud turbine speed to decrease. However, to maintain the maximum regulated DC power output from the voltage regulator 35, the turbine speed must always exceed some minimum requirement. For purposes of example, the turbine speed should exceed 2500 rpm to maintain the maximum DC power output. Below 2500 rpm, the alternator 16 and the regulator 35 will provide regulated DC voltage but at a power which is reduced due to the start-up load conditions.

Positive displacement pumps are conventionally used on drilling rigs to maintain the mud flow. The mud flow rate is therefore fairly constant with constant pump rpm. The constant flow rate curves in FIG. 3 are turbine load lines and characterize the decrease in turbine speed with increase in load. For mud flow rates below 300 gpm, all turbine load lines intersect line *ab* which corresponds to the minimum input speed, 2500 rpm, to the alternator 16 and regulator 35 required for the generation of maximum regulated DC power. If the electrical load which occurs during the acoustic transmitter turn-on and which appears as a mechanical load on the mud turbine 15 is sufficient to decrease the turbine speed below 2500 rpm, then loss of maximum regulated DC power occurs and adequate power may not be available to start the induction motor 23 of the acoustic transmitter. After the induction motor 23 is turned ON, it requires the major portion of the available power. If during the operation of the acoustic transmitter the turbine speed drops below the minimum speed required to maintain maximum available regulated DC power, then erratic acoustic transmitter operation could result. To avoid these problems of starting and operating the acoustic transmitter, the transmitter controller of the present invention is provided to initiate acoustic transmitter turn-on at a predetermined turbine speed sufficient to ensure that the turbine operating point in FIG. 3 is on a load line which intersects line *bc*. If the load line intersects line *bc*, maximum regulated DC power is available from the regulator 35 for transmitter turn-on. For example, assume that the predetermined speed has been set to 3400 rpm for transmitter turn-on. As the mud pumps are turned ON, the mud flow rate increases and the mud turbine speed increases. As the turbine speed exceeds 1800 rpm, regulated, but less than maximum, DC power becomes available and all the electronic circuitry, except the acoustic transmitter and the DC/AC inverter 36, automatically turns ON. When the turbine speed attains 3400 rpm, the mud flow rate is greater than 310 gpm. The exact flow rate depends on the turbine load for the acoustic transmitter OFF condition power demand. This power demand is generally low. All turbine characteristic curves for flow rates above 310 gpm intersect line *bc*. Therefore, maximum regulated DC power will be available for transmitter start-up.

After the transmitter is turned ON, adequate regulated DC power continues to be available so long as the turbine speed exceeds a minimum value corresponding

to the required power demand of the entire logging-while-drilling system. To prevent erratic transmitter operation due to loss of regulated DC power during logging-while-drilling operations as discussed above, the transmitter controller functions to turn OFF the acoustic transmitter should the turbine speed drop below 2500 rpm, for example. The transmitter remains OFF until the turbine speed increases again to 3400 rpm.

The mud turbine speeds required to start-up and shutdown the acoustic transmitter of 3400 rpm and 2500 rpm, respectively, are used herein only as examples to aid in the understanding of the operation of a conventional borehole logging tool of the type disclosed, for example, in the aforementioned patent to Godbey. The transmitter controller of the present invention may be designed to operate with any operating speeds of the mud turbine for which acoustic transmitter control is sought. The important consideration in choosing the mud turbine speed at which the transmitter controller is to be started is that the power generated at such speed be sufficient to prevent the sudden load generated by the acoustic transmitter upon start-up from causing the turbine speed to drop below a speed necessary to maintain adequate starting power.

Having now described both the mechanical and electrical features of an example of a conventional logging-while-drilling system to which the transmitter controller of the present invention may best be directed, there will now be described in detail, in connection with FIGS. 4 and 5, a preferred embodiment of the transmitter controller of the present invention.

Referring now to FIG. 4, there is illustrated the detailed schematic diagram of the transmitter controller of the present invention comprising a turbine speed detector 41, a power detector 42, an electronic switch 43, and an ON-OFF control 44. Input to the turbine speed detector 41 is supplied by one of the three outputs of the three-phase alternator 16. The frequency of each of the three-phase components of the input voltage is proportional to the speed of the shaft of alternator 16 and, consequently, proportional to the mud turbine speed. This relationship is as follows:

$$f = (P/2)(M/60)$$

(1)

where,

$f$  = frequency in Hz,

$P$  = number of poles, and

$M$  = speed of shaft in rpm.

This input is represented by the waveform  $V_a$  in FIG. 5.

Turbine speed detector 41 comprises a monostable multivibrator section 45 and a low-pass filter section 46. Monostable multivibrator 45 is biased such that the collector voltage of the output transistor 47 is at zero volts when the multivibrator is in the OFF condition. Each time the input  $V_a$  passes through zero volts in the negative-going direction, transistor 49 is triggered and the monostable multivibrator 45 provides a fixed amplitude and fixed pulse width digital signal  $V_b$  at the output of transistor 47, the period of digital signal  $V_b$  thereby being the same as the period of the alternating current input  $V_a$ . Digital signal  $V_b$  as illustrated in FIG. 5 varies between the limits of  $b_1$  when the monostable multivibrator 45 is in the OFF condition to a level of  $b_2$

when the monostable multivibrator 45 is triggered. Upon triggering of monostable multivibrator 45, the digital signal  $V_b$  remains at the  $b_2$  level for a period in the order of one millisecond. Digital signal  $V_b$  is applied to the minus input of the operational amplifier 48 of the low-pass filter section 46. The low-pass filter section 46 generates an output signal  $V_c$  which is a DC voltage with amplitude proportional to the period of the digital signal  $V_b$ . Output signal  $V_c$  thereby directly represents the mud turbine speed as set forth in Equation (1) above and is therefore proportional to the power available for starting and operating the acoustic transmitter. A sample waveform for the output signal  $V_c$  is illustrated in FIG. 5. The level  $c_1$  represents the voltage level at which the turbine speed reaches 2500 rpm, and the level  $c_2$  represents the voltage level at which the turbine speed reaches 3400 rpm.

The output signal  $V_c$  from the low-pass filter section 46 of the turbine speed detector 41 is applied as input to power detector 42. Power detector 42 comprises an inverting DC amplifier 50 and an output gate 51. Gate 51 is a logic inverter which is set to a logic 0 when the output of transistor 52 of inverting DC amplifier 50 is below the threshold voltage level required to set gate 51. When the inverting amplifier 50 provides an output which exceeds the threshold voltage level of gate 51, gate 51 is set to a logic 1. These logic settings of gate 51 are illustrated in FIG. 5 as waveform  $V_d$ . When logging-while-drilling operations are initiated and the mud turbine reaches the speed of 3400 rpm, the input  $V_c$  to transistor 52 reaches the voltage level  $C_2$  and transistor 52 provides an output which exceeds the threshold voltage level required to set gate 51 to a logic 1. Gate 51 remains in the logic 1 state until the mud turbine speed drops to the level of 2500 rpm, at which time the input  $V_c$  is at the level  $C_1$  and gate 51 returns to the 0 logic state. It can be noted in FIG. 4 that the output of gate 51 is fed back to the base input of transistor 52 of the inverting amplifier 50. This feedback maintains the collector voltage of transistor 52 at a level which exceeds the threshold voltage level for setting the gate 51 until such time as the mud turbine speed has dropped below 2500 rpm.

The electronic switch 43 is turned ON and OFF by the power detector 42. Electronic switch 43 comprises an input gate 53 and a transistor stage 54. Upon mud turbine speed exceeding 3400 rpm and output gate 51 of power detector being set to a logic 1 state, the input gate 53 of electronic switch 43 is set to a logic 0. This logic 0 state of input gate 53 biases transistor 53 to an OFF condition, which is the ON state for the electronic switch 43, thereby opening the line 55 leading to ON-OFF control section 44. Line 55 remains open until such time as the mud turbine speed drops below 2500 rpm, at which time input gate 53 is set to a logic 1, thereby driving transistor 55 into a condition of saturation, which is the OFF state for the electronic switch 43, and setting output line 55 to ground potential. The logic state of input gate 53 is represented by the waveform  $V_e$  in FIG. 5.

ON-OFF control section 44 is controlled directly by the ON-OFF state of electronic switch 43. Prior to the mud turbine speed initially reaching 3400 rpm, electronic switch 43 is OFF and the ground potential on line 55 disables the voltage regulator 56 of ON-OFF control section 44. During this period of time, a control signal  $V_f$  of voltage regulator 56 is at a first state of zero

volts. This control signal applied, by way of line 57 directly to the DC/AC inverter 36, disables the DC/AC inverter 36, thereby preventing AC power from being applied to the induction motor 23 of the acoustic transmitter. Upon the mud turbine speed reaching 3400 rpm, the electronic switch 43 is turned ON, opening the line 55 to ON-OFF control section 44. This enables the voltage regulator 56 to change the control signal  $V_f$  to a second state at a voltage level of  $f_1$ . Transistor 58 is provided to increase the output current-carrying capability. The voltage level  $f_1$  of control signal  $V_f$  when applied by way of line 57 to the DC/AC inverter 36 is sufficient to enable the DC/AC inverter 36 to apply the required power to the induction motor 23 for starting the acoustic transmitter. ON-OFF control section 44 maintains the control signal  $V_f$  at the level  $f_1$  so long as the electronic switch 43 is in the ON state. Upon the mud turbine speed dropping below 2500 rpm, the electronic switch 43 is turned OFF, thereby disabling the ON-OFF control section 44 whereby the control signal  $V_f$  returns to the first state of zero volt, the DC/AC inverter 36 is disabled, and the induction motor of the acoustic transmitter is shut down.

It is to be understood that the transmitter controller illustrated in FIG. 4 is merely representative of one embodiment of the present invention. In such embodiment, various types and values of circuit components may be utilized. In accordance with the specific embodiment illustrated in FIG. 4, the following TABLE I sets forth specific types and values of the circuit components:

TABLE I

| Reference Designation    | Description                |
|--------------------------|----------------------------|
| Transistors 47,49        | 2N2907 (Texas Instruments) |
| Transistors 52,54        | 2N2483 (Texas Instruments) |
| Transistors 58           | 2N4912 (Motorola)          |
| Operational Amplifier 48 | MC1556G (Motorola)         |
| Gates 51,53              | 1/2 CD4011D (RCA)          |
| Voltage Regulator 56     | μA723 (Fairchild)          |
| $V_G$                    | +15 volts DC               |
| $V_H$                    | -15 volts DC               |
| $V_f$                    | +10 volts DC               |
| Diode                    | 620 (Texas Instruments)    |
| Capacitor C1,3           | 1 μf                       |
| Capacitor C2             | 0.1 μf                     |
| Capacitor C4             | 500 pf                     |
| Resistor                 |                            |
| 1                        | 39 K ohms                  |
| 2                        | 30 K ohms                  |
| 3                        | 4 K ohms                   |
| 4                        | 1 K ohms                   |
| 5,7,9                    | 10 K ohms                  |
| 6                        | 24.9 K ohms                |
| 8                        | 50 ohms                    |
| 10                       | 402 K ohms                 |
| 11                       | 499 K ohms                 |
| 12,16                    | 49.9 K ohms                |
| 13                       | 301 K ohms                 |
| 14                       | 8.7 K ohms                 |
| 15                       | 5.1 K ohms                 |
| 17                       | 2 K ohms                   |
| 18                       | 1.5 K ohms                 |
| 19                       | 1 ohm                      |

It is to be understood that the foregoing described embodiment of the transmitter controller may be utilized with any rotary power source and acoustic transmitter which are suitable for use in a borehole logging tool of a logging-while-drilling system. The detailed description of the generation of the power required to operate the acoustic transmitter and the generation and modulation of the acoustic waves represents the operation of one embodiment of a borehole logging-while-drilling system suitable for control by the transmitter controller of the present invention. The transmitter

controller may be utilized with various modifications to both the power source and the acoustic transmitter without departing from the scope and spirit of the invention. Also, various modulation techniques such as, for example, amplitude modulation, frequency shift keying, or phase shift keying may be utilized. Similarly, various modifications to the disclosed embodiment of the transmitter controller itself may become apparent to one skilled in the art without departing from the scope and spirit of the invention as hereinafter defined by the appended claims.

What is claimed is:

1. A logging-while-drilling tool comprising:

- a. an elongated housing adapted for insertion into a borehole, and through which drilling fluid is circulated during drilling operation,
- b. a rotary-driven member responsive to the hydraulic power in said drilling fluid for generating mechanical power,
- c. means for converting said mechanical power to electrical power, said electrical power being of alternating current with a frequency directly proportional to the speed of said rotary driven member,
- d. an acoustic transmitter, driven by said electrical power, said acoustic transmitter periodically interrupting the flow of said drilling fluid through said housing so as to produce a continuous acoustic wave in the drilling fluid,
- e. means for modulating said acoustic wave in response to a measured downhole condition, the modulated acoustic wave passing upward through the drilling fluid to the surface of the earth where it is demodulated to provide a readout of the measured condition,
- f. means for converting the frequency of the alternating current of said electrical power to an analog signal of amplitude proportional to the frequency of said alternating current, such analog signal thereby representing the speed of said rotary-driven member, and
- g. means responsive to said analog signal for providing a control signal of a first state when said analog signal initially exceeds a first voltage level representing the speed of said rotary-driven member required for the generation of the required starting power for said acoustic transmitter and of a second state when said analog signal, after initially exceeding said first voltage level, drops below a second voltage level representing the speed of said rotary-

driven member required for the generation of the required operating power for maintaining continuous operation of said acoustic transmitter, said second voltage level being lower than said first voltage level.

2. The tool of claim 1 wherein said means for converting the frequency of the alternating current of said electrical power to an analog signal comprises:

- a. means responsive to said alternating current for generating a digital signal of fixed amplitude and pulse width, the period of said digital signal being the same as the period of the frequency of said alternating current, and
- b. means for converting said digital signal to an analog signal whose amplitude varies in accordance with the period of said digital signal.

3. The tool of claim 1 wherein said means for providing said control signal comprises:

- a. a detector with input supplied by said analog signal, said detector providing a digital output of a first logic level when the amplitude of said analog signal has initially exceeded said first voltage level and has not thereafter dropped below said second voltage level and of a second logic level when the amplitude of said analog signal has not initially exceeded said first voltage level or has, after exceeding said first voltage level, thereafter dropped below said second voltage level,
- b. a switch coupled to said detector which is turned ON when the digital output of said detector is at said first logic level and is turned OFF when said digital output is at said second logic level, and
- c. means operable in response to the setting of said switch for providing said control signal, said control signal enabling the acoustic transmitter during the period when said switch is turned ON.

4. The logging-while-drilling tool of claim 1 wherein said detector comprises:

- a. an amplifier to which said analog signal is applied, and
- b. a gate having its input connected to the output of said amplifier and having its output connected through a feedback path to the input of said amplifier, whereby said gate is set to said first logic level when said analog signal exceeds said first voltage level and is maintained at said first logic level by means of said feedback path until said analog signal drops below said second voltage level.

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