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Griffin, III et al.

[11] **3,746,102**

[45] **July 17, 1973**

[54] **AUTOMATIC DRILLING BREAK ALARM AND SHUTDOWN SYSTEM**

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[52] **U.S. Cl.** **173/4,** 175/27

[51] **Int. Cl.** **E21b 19/08**

[58] **Field of Search** 173/4, 6, 151.5; 175/27

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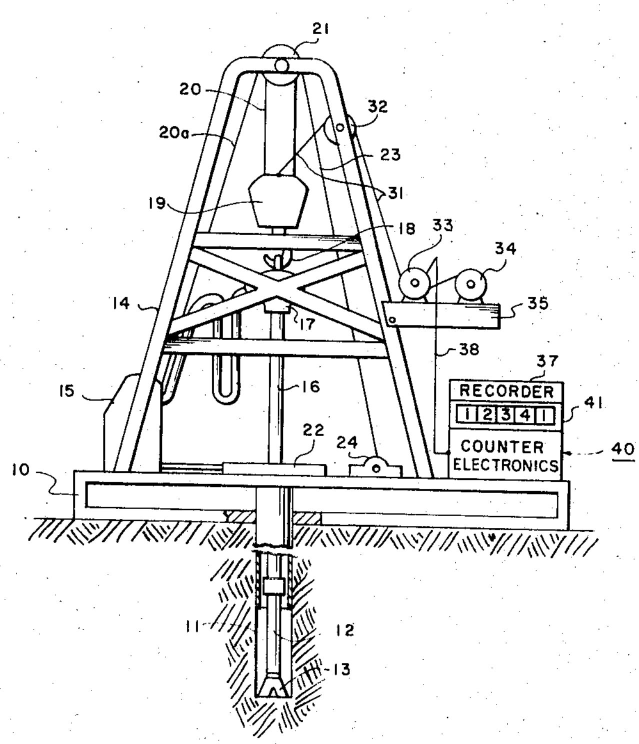
[57] **ABSTRACT**

The rate of penetration of a drill bit and associated drill string used in drilling oil and gas wells is monitored and the resulting output signal activates an alarm whenever the rate of penetration exceeds a predetermined level. The depth of penetration is also monitored during the time that the rate of penetration is excessive and when the depth interval during such time exceeds a given number of feet, a second alarm is sounded. When the depth interval during the excessive rate of penetration is greater than a second predetermined number of feet, a signal is sent to the drawworks which takes the weight off the bit. Means are also provided for resetting the depth counting mechanisms whenever either of the depth interval circuits have counted to less than their predetermined capacity whenever the rate of penetration has diminished to a point which is less than the predetermined excessive level. In an alternative embodiment, predetermined time intervals are used instead of depth intervals.

7 Claims, 4 Drawing Figures



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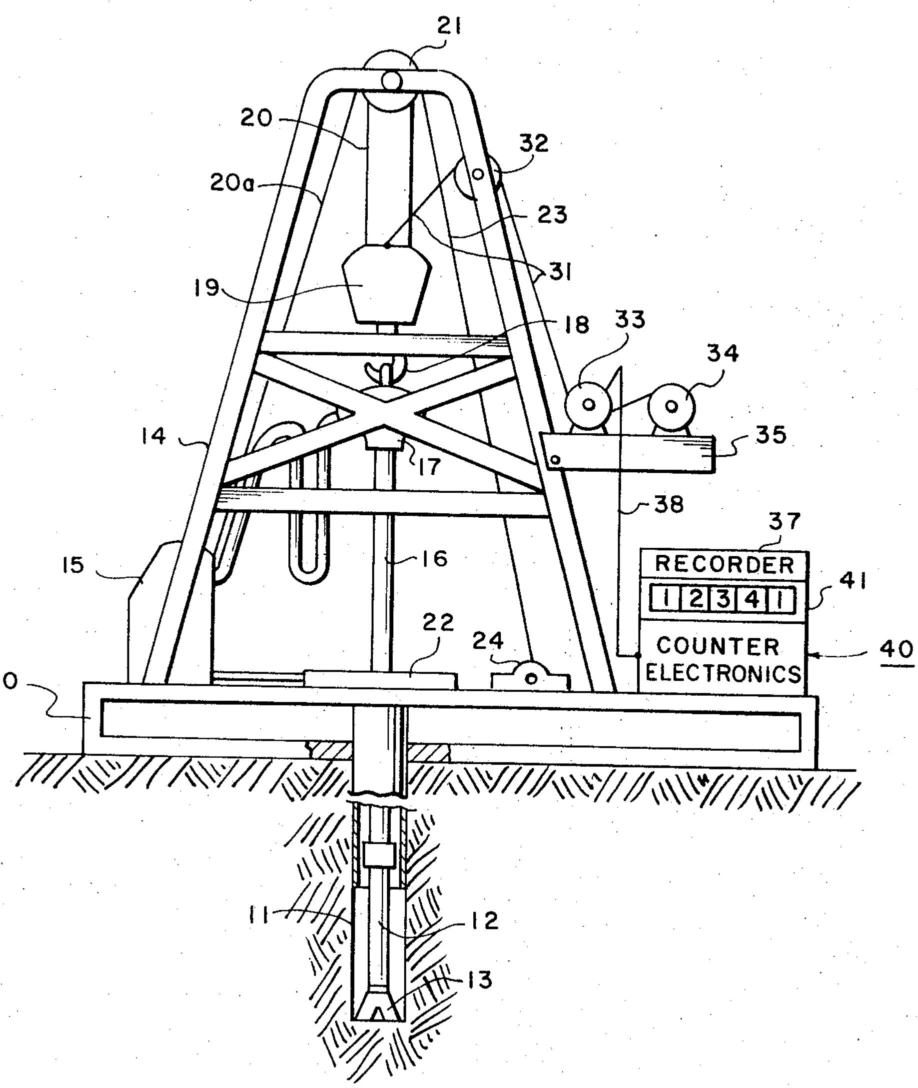

FIG. 1

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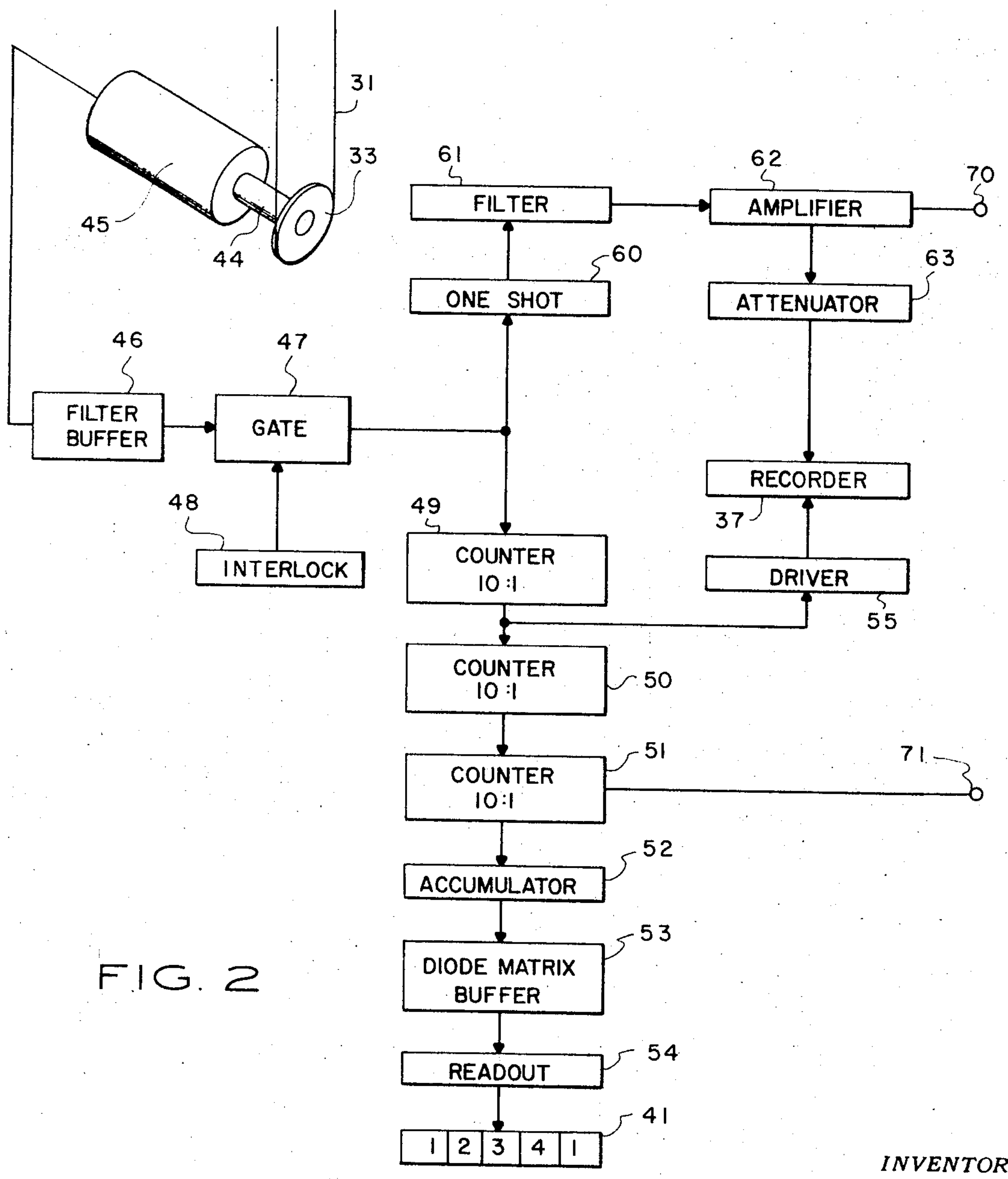

FIG. 2

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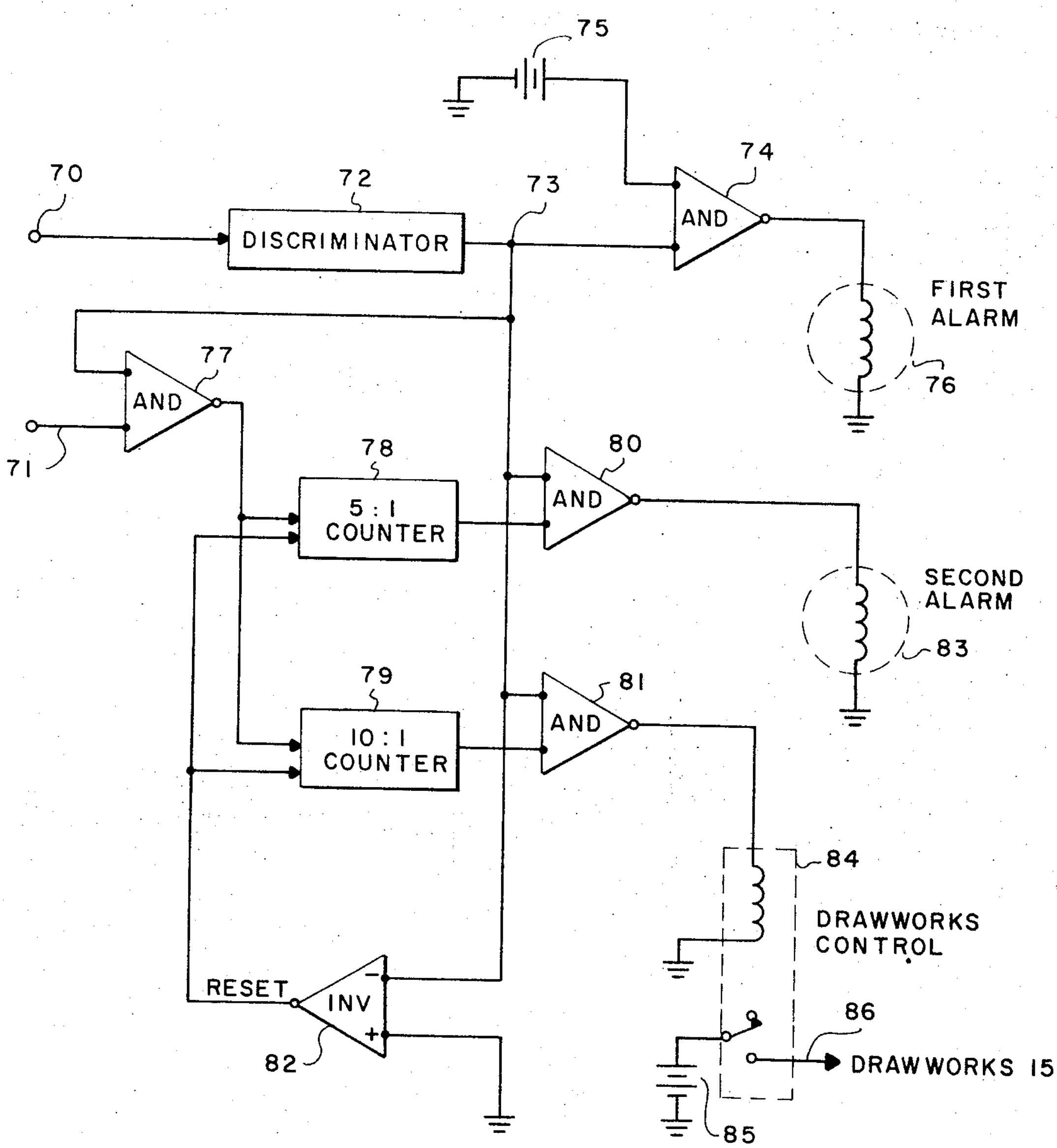

FIG. 3

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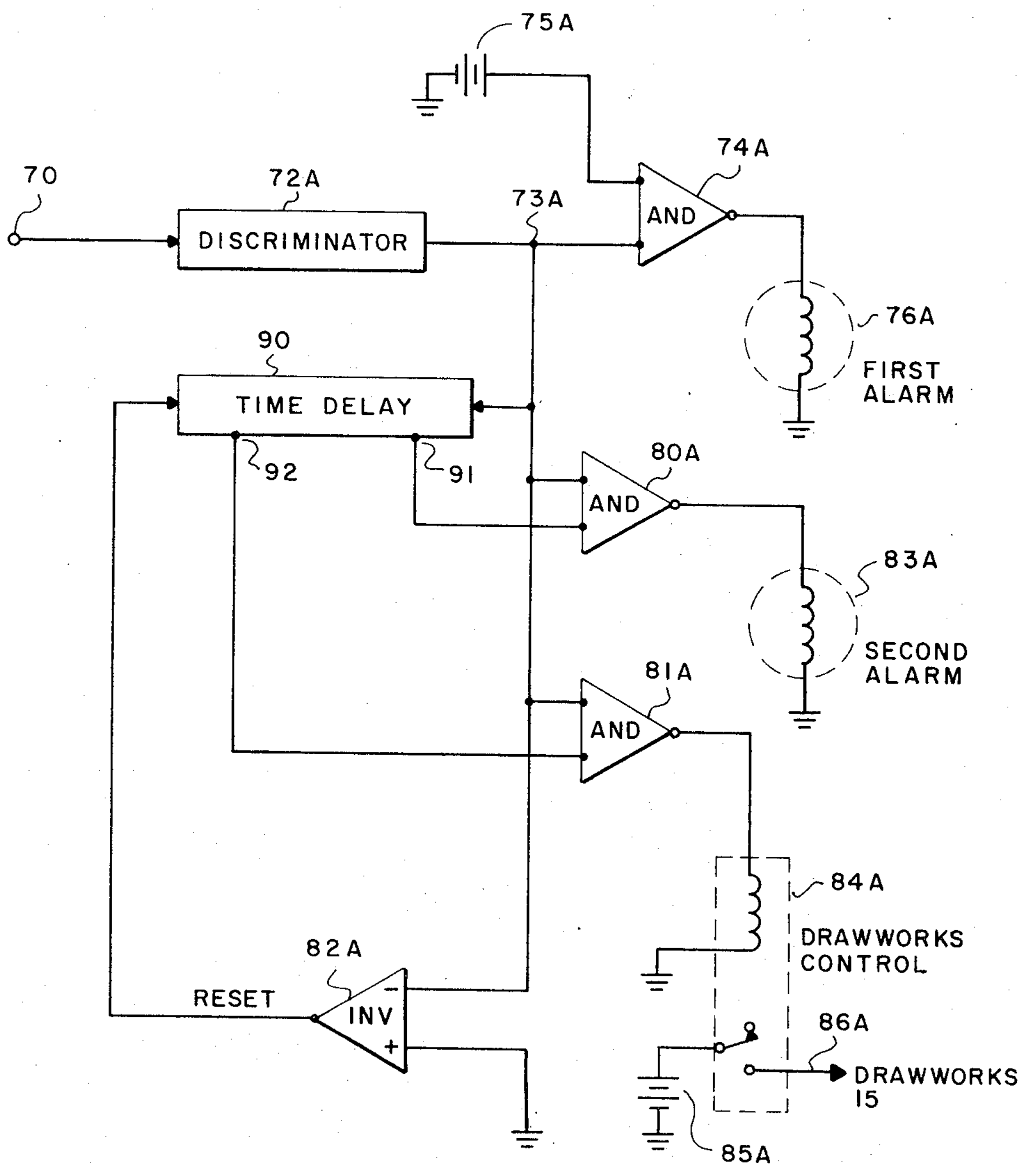

FIG. 4

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AUTOMATIC DRILLING BREAK ALARM AND SHUTDOWN SYSTEM

BACKGROUND OF THE INVENTION

This invention relates generally to systems used in the drilling of oil and gas wells and specifically to a system for monitoring the rate of penetration of a drill bit and its associated drill string and for the activation of one or more alarms and the automatic control of the drawworks whenever the rate of penetration of the bit in the earth formations has exceeded a predetermined level for predetermined time or depth intervals within the formations.

In the art of drilling oil and gas wells in earth formations, it is well known that an increased rate of penetration (ROP) of the drill bit indicates the existance of potentially dangerous situations, not the least of which is the entry of the drill bit and drill string into a gas pocket which may cause a blow-out of the well. In such situations, it is generally considered desirable to cease the drilling operation, for example, as by lifting the weight of the drill string off the bit. In the manual operations of conventional drilling rigs, this is accomplished by the driller observing an ROP indication meter and by his manually controlling the drawworks should the ROP be excessively high.

It should be appreciated that the sudden upsurge of the ROP is termed a drilling "break" by those in the art.

Although it has been known in the art to make a manual observation of such a drilling break and to manually control the drawworks in response to such an observation it has heretofore been unknown to automatically control the drawworks in response to signals indicative of such a break, especially in conjunction with predetermined time or depth intervals or other such varying parameters.

It is therefore the primary object of this invention to provide a system for monitoring the ROP of a drill bit in the earth formations and for the activation of associated systems for discontinuing the drilling operation whenever the ROP exceeds a given level for a given depth interval;

It is another object of the invention to provide a system which monitors the ROP of a drill bit and related drill string and causes the drilling operation to be automatically interrupted in response to the ROP exceeding a predetermined level during a predetermined time interval;

It is yet another object of the invention to provide a system for monitoring the ROP of a drill bit and related drill string and for automatically causing an alarm to be activated when the ROP exceeds a predetermined level during a predetermined depth interval of the drill bit within the earth formations;

It is still another object of the invention to provide a system for monitoring the ROP of a drill bit and related drill string and for automatically causing an alarm to be activated whenever the ROP exceeds a predetermined level during a predetermined time interval;

It is yet another object of the invention to provide a system for automatically manipulating the drawworks of an oil and gas well drilling rig in response to the rate of penetration of the drill bit exceeding a predetermined level; and

It is another object of the invention to provide a system for automatically manipulating the drawworks of

an oil and gas well drilling rig in response to the rate of penetration of the drill bit exceeding a predetermined level during a predetermined interval.

The objects of the invention are accomplished, broadly, by a system which monitors the ROP of a drill bit and related drill string and which automatically causes the drawworks associated with the drill string to be manipulated in response to the monitored ROP. In one feature of the invention, the drawworks is controlled in response to the predetermined ROP level being exceeded for a predetermined time interval. In still another feature of the invention, the drawworks is manipulated after the ROP of the drill bit has exceeded the predetermined level during a predetermined depth interval of the bit. Other features of the invention relate to one or more alarm systems being activated whenever the ROP of the bit has exceeded a predetermined level during predetermined time or depth intervals.

These and other objects, features and advantages of the invention will be apparent to those skilled in the art from a reading of the following detailed specification and drawing, in which:

FIG. **1** is a schematic elevational view, partly in cross section, of a system according to the present invention;

FIG. **2** is a block diagram of circuit for use in monitoring the ROP and depth of penetration of a drill bit in accordance with the present invention;

FIG. **3** is a schematic illustration of a circuit for utilizing the monitored ROP as a function of depth intervals of the drill bit within the earth formations and for activating alarms and the drawworks as a function of such signals; and

FIG. **4** is a schematic illustration of an alternative embodiment of the present invention wherein the monitored ROP is used to activate alarms and the drawworks as a function of the ROP exceeding a predetermined level during a predetermined time interval.

Referring now to the drawing in greater detail, especially to FIG. **1**, there is illustrated schematically a system for determining the ROP and depth of a drill bit in a well bore according to the invention. A drilling platform **10** is mounted on the earth's surface from which an earth borehole **11** has been drilled. Within the borehole **11** is a pipe string **12**, to the lower end of which is attached a drill bit **13.** A derrick **14** is mounted on the platform **10**, with its conventional drawworks **15.** The drill string **12** comprises a number of joined sections of pipe terminating in a kelly **16,** followed by a swivel **17,** a hook **18** and a traveling block **19** suspended by a drilling line **20** from a crown block **21.** The drawworks also drive a rotary table **22** which in turn transmits the drive to the kelly **16.** One end of the line **20**, namely the fast line **20a**, is taken to the drawworks **15** which contain the motor or motors for manipulating the drill string.

The other end of the drilling line is secured to the anchor **24.** The portion **23** of the line which extends between the anchor **24** and the top of the crown block **21** is called the deadline.

Although not illustrated, the anchor member **24** normally would include a winding-on drum and can also, if desired, contain a dead-line sensor for monitoring the weight on the bit, for example, as shown in U.S. Pat. No. 3,461,978 to F. Whittle, issued Aug. 19, 1969.

Referring further to FIG. **1**, there is illustrated a wireline **31** connected at one end to the traveling block **19**, passing over a wheel **32** mounted on the derrick **14.**

The wireline 31 then passes over the wheel 33 to a rewind drum 34, the wheel 33 being shown in more detail in FIG. 2. The wheel 33 and rewind drum 34 are each mounted on a support member 35 attached to the derrick 14, or some other such suitable point. As is explained with respect to FIG. 2, the wheel 33 drives a pulse generator having a voltage output on conductor line 38 connected to the circuitry 40 bearing the legend "counter electronics." A visual monitor 41 and recorder 37 are mounted above the counter electronics section 40. The circuitry 40 generally comprises the circuits illustrated in FIG.'s 2 and 3 or the alternative embodiment of FIG. 4.

Referring now to FIG. 2, there is illustrated the wheel 33, driven by the wireline 31, which in turn is adapted to drive the rotational encoder mechanism 45 which converts rotational movement (of the wheel 33) into electrical pulses. If desired, the encoder as described in U.S. Pat. No. 3,426,303 to Guy O. Buckner, issued Feb. 4, 1969, assigned to the assignee of the present invention, can be used for this purpose. Thus, as the wheel 33 turns, electrical pulses appear on conductor 38. By conventional gearing, the output of the mechanism 45 produces one hundred electrical pulses, each preferably having a square wave output, for each revolution of the shaft 44. The output of the apparatus 45 is coupled into a conventional filter and buffer section 46 and then into a gate circuit 47. Also coupled into the gate 47 is an interlock circuit 48, which may be, if desired, merely a manual switch which may be operated by the operator to close the gate 47 whenever the cable 31 reverses direction. Such an interlock is desirable to thus provide an electrical indication of travel only whenever the traveling block and kelly assembly is moving in the downward direction. If desired, however, the interlock circuitry 48 can be automatically responsive to the movement of the kelly in a downward direction and also act to close the gate 47 whenever the kelly is moving in the upward direction, as, for example, through a one-way clutch. If desired, the interlock circuit 48 could be made automatically responsive to a given speed of the drill bit, to weight on the bit, or mud pump pressure, to name but a few examples.

The output of the gate 47 is illustrated to travel in two directions. In the one direction, the output of the gate 47 drives a series of electronic counters 49, 50 and 51, each of said counters preferably having a 10:1 ratio. Thus, for each of the counters having such a ratio, for each ten pulses into the counter, only one pulse is seen on its output. The output of the counter 51 is then coupled into a conventional accumulator circuit 52 which drives a diode matrix and buffer circuit 53 which in turn drives the readout section 54. The readout section 54 drives a visual depth monitor 41.

In the operation of the circuit of FIG. 2 thus far described, by proper gearing (not illustrated), the shaft 44 makes 20 revolutions for each 2 feet of travel of the cable 31. For each foot of travel, the shaft 44 makes ten revolutions. Since the device 45 creates 100 pulses per revolution, the output of the device 45 is thus seen to be 1,000 pulses per one foot of travel of the cable 31. Since the series of counters 49, 50 and 51 create a reduction of one output for each one thousand pulses in from the gate 47, it should be appreciated that the output of counter 51 therefore causes there to be one pulse per each foot of travel of cable 31. The output of the accumulator 52, as represented by five decades of BCD readout having 21 lines, is then coupled into the diode matrix 53 to drive the readout circuit 54 and visual monitor 41.

The output of counter 49, having an electrical output of one hundred pulses for each foot of travel of the cable 41, is coupled into the driver circuit 55 which drives the recorder 37, for example, a pulse driven recorder commercially available from Texas Instruments, Incorporated of Dallas, Texas, such a recorder thus being driven as a function of movement of the cable 41, and hence depth of the drill bit. Such a recorder conventionally has a vertical scale wherein 5 inches is representative of 100 feet of travel. Since the output of the counter 49 is 100 pulses per foot of travel, the driver circuit 55 converts the 100 cycle per foot information into that necessary to cause one inch of travel by the recorder paper in the recorder 37 for every 20 feet of travel by the cable 41.

The output of gate 47 is also connected into a one shot multivibrator 60, the output of which is coupled into a filter 61 to drive an operational amplifier 62. The output of the amplifier 62 is coupled into an attenuator 63 to drive the recorder 37. Since the output of the amplifier 62 is indicative of the rate at which the one shot multivibrator 60 fires, the output of the amplifier 62 is indicative of the rate at which the cable 41 is moving and hence the rate of penetration of the drill bit used in conjunction with the system. The output of the amplifier 62 is preferably set from 0 to 5 volts DC, the amplitude of which is directly proportional to the rate of penetration of the drill bit. Since the recorder 37 is driven in conjunction with the total depth at which the drill bit is found, it should be appreciated that the rate of penetration of the drill bit is recorded as a function of depth of the drill bit on the recorder 37.

For reasons as set forth hereinafter, the output of the amplifier 62 is connected to output terminal 70 and the output of counter 51 is connected to output terminal 71.

Referring now to FIG. 3, the junction 70 is connected to the input of a voltage discriminator 72 whose output is connected to the junction 73. The junction 73 is connected to one of the two inputs of an AND gate 74 whose other input is connected to a battery 75. The output of the AND gate 74 is connected to an alarm mechanism 76, bearing the legend "First Alarm." The alarm mechanism 76 may be a visual monitor, for example, a red light, or may be an audible alarm, for example, a horn or a siren.

The junction 73 is also connected to one of the two inputs to the AND gate 77, the other input to the AND gate 77 being connected to the terminal 71. The output of the AND gate 77 is connected to the input of a 5:1 counter 78 and to the input of a 10:1 counter 79. The output of the counter 78 is connected to one of the inputs of a two input AND gate 80 whose other input is connected to the terminal 73. The output of the counter 79 is connected to one of the inputs of a two input AND gate 81 whose other input is connected to the terminal 73. The terminal 73 is also connected to the inverting or negative input of the inverter 82 whose positive input is grounded. The output of the inverter 82 is connected to the reset inputs of the counters 78 and 79. The output of the AND gate 80 is connected to an alarm mechanism 83, bearing the legend "Second Alarm." It should be appreciated that the alarm mechanism 83 may also be a visual or an audible alarm, or a combination of the two, as was discussed with respect to the alarm mechanism **76**.

The output of the AND gate **81** is connected to the coil of a relay **84**, bearing the legend "Drawworks Control." The wiper arm of the control relay **84** is connected to a battery **85** or some other such suitable power source and the normally open contact of the relay **84** is connected by conductor **86** to the drawworks **15**.

In the operation of the circuit of FIG. **3**, it should be appreciated that the signal appearing at the terminal **70** is a 0–5 VDC signal representative of the ROP of the drill bit. The signal appearing at terminal **71** is a pulsed DC signal, each such signal being indicative of one foot of depth of the drill bit. The discriminator **72** provides voltage discrimination on the incoming ROP signal such that no signal appears at terminal **73** unless the voltage appearing at terminal **70** exceeds a predetermined level. For example, the discriminator could be set at the 4.0 VDC level and pass only those signals above that level. Assuming that a signal does appear at terminal **73**, this signal, in conjunction with the voltage source **75** to the other input to the AND gate **74**, causes the AND gate **74** to be gated and the alarm **76** to be activated as an indication that the predetermined level of ROP has been exceeded. If desired, although not illustrated, a delay line can be inserted ahead of the alarm **76** to prevent transient excursions of the ROP from activating the alarm **76**.

The signal appearing at terminal **73** also causes the AND gate **77** to be gated in conjunction with a signal indicative of depth appearing at terminal **71**. Thus, each time a depth pulse appears on terminal **71** and the input from terminal **73** is present, the AND gate **77** produces an output pulse at its output which is coupled into each of the counters **78** and **79**. As soon as the counter **78** has received five such pulses from the AND gate **77**, the counter **78** will produce one output pulse which indicates that the drill bit has traveled 5 feet since experiencing the drilling brake. The output of the counter **78** drives one of the inputs of the AND gate **80** and when a signal is still present on the terminal **73**, the AND gate **80** is gated and the alarm **83** is thereby activated. Should the counter **78** have counted to a number less than five, for example, four, and the signal is no longer present on the terminal **73**, meaning that the ROP is now less than the predetermined 4 volt level, the signal is thus lost to the negative input of the inverter **82** and a positive signal is thus produced at the output of the inverter **82**, bearing the legend "reset." The counter **78** is thus reset to its zero counting position.

The AND gate **77** also drives the counter **79** which produces an output pulse in response to ten input pulses, i.e., the counter **79** produces an output pulse for each 10 feet of travel of the drill bit. In such an event, the AND gate **81** is gated if the signal is still present on terminal **73** and output pulse is thereby produced at the output of the AND gate **81** to activate the drawworks control relay **84**. The activation of the relay **84** causes the voltage source **85** to be applied from the wiper arm of the relay **84** to the normally open contact of the relay **84** to thus place the voltage source **85** on the conductor **86** which leads to the drawworks **15** and thereby manipulate the drawworks. Such manipulation would normally involve picking the weight up from the drill bit but could also involve other manipulations, for example, the cessation of rotation of the drill string. In the event the counter **79** has counted to some number less than 10, for example weight, the reset inverter **82** has an output voltage as was discussed with respect to the counter **78** and the counter **79** is returned to its zero counting position.

Thus, it should be appreciated that the circuit of FIG. **3** provides a first alarm when the ROP signal appearing at **70** has exceeded a predetermined level and a second alarm when the drill bit has traveled for a predetermined depth interval, for example, five feet and ultimately provides the control of the drawworks when the drill bit has traveled for a second predetermined depth interval, for example, 10 feet.

Referring now to FIG. **4**, there is illustrated an alternative embodiment of the present invention wherein the two alarms and the drawworks control relay are activated in response to the predetermined ROP level being exceeded for a given time interval as opposed to a predetermined depth interval or intervals as discussed above with respect to FIG. **3**. The terminal **70** is connected in FIG. **4** to a voltage discriminator **72A** whose output is connected to the junction **73A** and one of the inputs to an AND gate **74A**. The other input of the AND gate **74A** is connected to a voltage source **75A**. The output of the AND gate **74A** is connected to an alarm mechanism **76A** bearing the legend "First Alarm." The junction **73A** is also connected to the input of a time delay circuit **90**, circuit **90** having a first output **91** and a second output **92**. The output terminal **91** is connected to one of the inputs of an AND gate **80A** whose other input is connected to the junction **73A**. The output of the AND gate **80A** is connected to an alarm mechanism **83A**. bearing the legend "Second Alarm." The output **92** of the time delay circuit **90** is connected to one of the inputs to an AND gate **81A** whose other input is connected to the junction **73A**. The output of the AND gate **81A** is connected to the coil of relay **84A**, bearing the legend "Drawworks Control." A voltage source **85A** is connected to the wiper arm of the relay **84A** and a conductor **86A** is connected to the normally open contact of the relay **84A** leading to the drawworks **15**. The junction **73A** is also connected to the inverting or negative input of the inverter **82A** whose positive input is grounded. The output of the inverter **82A**, bearing the legend "Reset" is connected to the time delay circuit **90**.

In the operation of the circuit of FIG. **4**, the signal appearing at input terminal **70** is coupled through the voltage discriminator **72A** whose discrimination level is set at a predetermined level, for example, 4 VDC. Thus, no voltage appears at junction **73A** to gate the AND gate **74A** unless the predetermined voltage level has been exceeded. In the event of excessive ROP, the AND gate **74A** is gated and the alarm **76A** is activated. The signal appearing at **73A**, indicative of excessive ROP, is also coupled into the time delay circuit **90**. After a predetermined first delay, for example, **15** seconds, a signal appears at the terminal **91** which gates the AND gate **80A** if the excessive ROP signal is still present on the terminal **73A** to provide the other input to AND gate **80A**. In such an event, the AND gate **80A** is gated and the alarm **83A** is activated. After a second predetermined time interval, for example, 30 seconds, a signal appears at the output terminal **92** and the AND gate **81A** is gated if the excessive ROP signal is still present at the junction **73A**. In such an event, a signal appears at the output of the AND gate **81A** and thus activates the drawworks control relay **84A** to provide the voltage source **85A** to the conductor **86A** which leads to the drawworks **15**.

In the event the signal is lost at junction **73A** prior to the first predetermined time interval being exceeded, for example, **14** seconds, the inverter **82A** provides a reset signal to the time delay **90** which causes the timing mechanism to be returned to zero status. Thus, if the excessive ROP is not present for at least the first predetermined time interval, the aforementioned example of **15** seconds, then the second alarm **83A** is not activated. In the event the second predetermined time interval is not exceeded, the timing circuit associated with the output terminal **92** is also reset to zero and the drawworks control is not activated.

In summary of the operation of the circuit of FIG. **4**, it should be appreciated that when the ROP of the drill bit exceeds a predetermined level, the alarm **76A** is activated. When the excessive ROP is present for a first predetermined time interval, the alarm **83A** is activated. When the excessive ROP is present for a second predetermined time interval, the drawworks control relay **84A** is activated and the drawworks thereby manipulated.

Thus, there has been illustrated and described herein the preferred embodiments of systems according to the invention for activating one or more alarm mechanisms and for controlling and manipulating the drawworks associated with the drill string and drill bit in conjunction with various depth and/or time intervals. It should be appreciated, however, that the examples of time and depth intervals are merely illustrative and should not be considered as being limiting factors. For example, instead of 5 and 10 foot depth intervals, the two predetermined depth intervals could be one and two feet or some other such number of drilled depth. Likewise, the time intervals could be time intervals other than the ones discussed. For example, instead of 15 and 30 second time intervals, the time intervals could be 30 seconds and 1 minute or some other such time interval as to provide the desired protection when experiencing a drilling brake. Likewise, those skilled in the art will recognize that pneumatic equivalents of the illustrated electrical circuits may be used if desired and that parameters other than depth and time intervals may be used to activate the alarm and control subsystems in the presence of excessive ROP of the drill bit. Furthermore, although in manipulating the drawworks the weight can be lifted directly from the bit, the preferred embodiment contemplates that the bit be allowed to continue to drill without moving the block to restore the weight. Thus the weight on the bit is "drilled off," but which nonetheless has the long term effect of lifting the weight off the bit.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A system for monitoring the rate of penetration of a drill bit in drilling an oil and gas well and for manipulating the drawworks associated with said drill bit in a manner functionally related to said monitored rate of penetration, comprising:

means for monitoring the rate of penetration of a drill bit in an earth formation and for generating a signal functionally related to said rate of penetration; and

means responsive to said signal for manipulating the drawworks associated with said drill bit to reduce the weight on said drill bit as a function of said rate of penetration being higher than a predetermined level during a first predetermined interval.

2. The system according to claim **1** wherein said first predetermined interval comprises a time interval.

3. The system according to claim **1** wherein said first predetermined interval comprises a depth interval.

4. The system according to claim **1** including in addition thereto means for activating a first alarm in response to said rate of penetration being higher than said predetermined level during a second predetermined interval.

5. The system according to claim **4**, including in addition thereto, means for activating a second alarm in response to said rate of penetration being higher than said predetermined level during said first predetermined interval.

6. The system according to claim **4** wherein said second interval precedes said first interval.

7. The system according to claim **4** wherein said first predetermined interval is greater than said second predetermined interval.

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