

PATENT SPECIFICATION

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- (21) Application No. 36888/72 (22) Filed 8 Aug. 1972
(31) Convention Application No. 191 693 (32) Filed 22 Oct. 1971 in
(33) United States of America (US)
(44) Complete Specification published 27 Dec. 1974
(51) International Classification E21B 45/00
(52) Index at acceptance
E1F 31D2 31X1 31X9
G1N 1A3B 1A6 1B3 1D7 3S1B 4C 7E1 7N



(54) AUTOMATIC DRILLING BREAK ALARM AND SHUTDOWN SYSTEM

(71) We, DRESSER INDUSTRIES INC., a corporation organised and existing under the laws of the state of Delaware, United States of America, of Republic National Bank Building, Dallas, Texas, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

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 existence 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 observa-

tion, 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.

According to the present invention there is provided a system for monitoring the rate of penetration of a drill bit in drilling an oil and gas well and for controlling 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 controlling the drawworks associated with said drill bit to reduce the weight on said drill bit when said rate of penetration is higher than a predetermined level for a first predetermined interval.

The invention will be better understood from the following description of preferred embodiments thereof, given by way of example only, reference being had to the accompanying drawings, wherein:

FIG. 1 is a schematic elevational view, partly in 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

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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 dead-line.

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. Patent No. 3,461,978 to F. Whittle, issued August 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 United States Letters

Patent No. 3,426,303 to Guy O. Buckner, issued February 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 mechanism 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 two feet of travel of the cable 31. For each foot of travel, the shaft 44 makes ten revolutions. Since the device 45 creates one hundred pulses per revolution, the output of the device 45 is thus seen to be one thousand 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 5 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 five inches is representative of 100 15 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 20 paper in the recorder 37 for every 20 feet of travel by the cable 31.

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 25 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 30 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 45 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 terminal 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 55 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 60 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 65 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 out- 70 put 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 75 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, 80 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 mech- 85 anism 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 90 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, 95 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 100 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 105 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. 120

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 125 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 130

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 break. 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 four 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 ten 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 an 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 control the drawworks. Such control would normally involve picking the weight up from the drill bit but could also involve the cessation of rotation of the drilling string. In the event the counter 79 has counted to some number less than ten, for example eight, 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, ten 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 drawworks control relay 84A is activated to effect control of the drawworks.

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 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 five and ten 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 break. 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 sub-systems in the presence of excessive ROP of the drill bit. Furthermore, although in controlling 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.

WHAT WE CLAIM IS:

1. A system for monitoring the rate of penetration of a drill bit in drilling an oil and gas well and for controlling 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 controlling the drawworks associated with said drill bit to reduce the weight on said drill bit when said rate of penetration is higher than a predetermined level for 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.

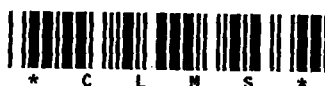
4. The system according to any preceding claim including means for activating a first alarm in response to said rate of penetration being higher than said predetermined level.

5. The system according to any preceding claim including means for activating a second alarm in response to said rate of penetration being higher than said predetermined level for a second predetermined interval.

6. The system according to claim 5 wherein said first predetermined interval is greater than said second predetermined interval.

7. A system for monitoring the rate of penetration of a drill bit, substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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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 drawworks control relay 84A is activated to effect control of the drawworks.

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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.

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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 controlling the drawworks associated with said drill bit to reduce the weight on said drill bit when said rate of penetration is higher than a predetermined level for 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 any preceding claim including means for activating a first alarm in response to said rate of penetration being higher than said predetermined level.

5. The system according to any preceding claim including means for activating a second alarm in response to said rate of penetration being higher than said predetermined level for a second predetermined interval.

6. The system according to claim 5 wherein said first predetermined interval is greater than said second predetermined interval.

7. A system for monitoring the rate of penetration of a drill bit, substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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