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Kelseaux et al.

[11] **3,898,880**

[45] **Aug. 12, 1975**

[54] **ELECTRONIC SUPERVISORY MONITORING METHOD FOR DRILLING WELLS**

[75] Inventors: **Ray M. Kelseaux; Harold J. Dobbs,** both of Tulsa, Okla.; **Frank D. Priehe,** Houston, Tex.

[73] Assignee: **Cities Service Oil Company,** Tulsa, Okla.

[22] Filed: **July 15, 1974**

[21] Appl. No.: **488,364**

Related U.S. Application Data

[63] Continuation of Ser. No. 335,191, Feb. 23, 1973, abandoned, which is a continuation-in-part of Ser. No. 156,645, June 25, 1971, Pat. No. 3,785,202.

[52] **U.S. Cl.** **73/151.5**

[51] **Int. Cl.**[2] **E21B 49/00**

[58] **Field of Search** 73/151, 151.5

[56] **References Cited**

UNITED STATES PATENTS

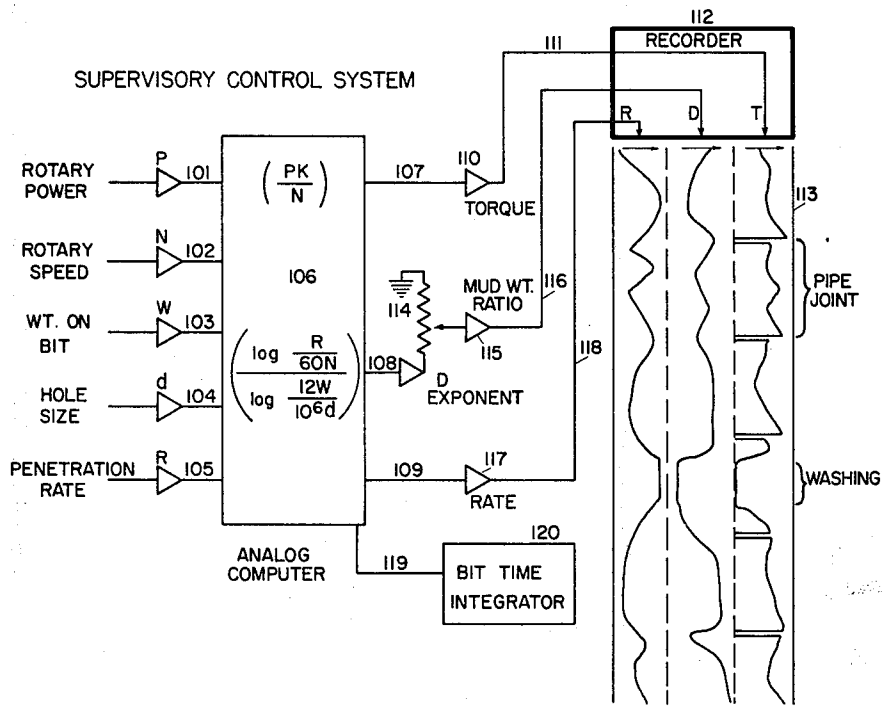
2,949,029	8/1960	Bayles et al.	73/136 A
3,368,400	2/1968	Jorden, Jr. et al.	73/151.5

Primary Examiner—Jerry W. Myracle
Attorney, Agent, or Firm—John W. Carpenter

[57] **ABSTRACT**

An electronic supervisory control system is disclosed herein wherein rotary power, rotary speed, bit weight, hole size, penetration rate and mud weight ratio are utilized in conjunction with analog and electronic sensing means in order to afford drilling personnel a supervisory control system over drilling operation. Recorded information includes the rate of penetration, corrected *d* exponent and rotary torque, which may be visually recorded and electronically stored for use for both supervisory control and simultaneous understanding of the monitored drilling variables and their effect upon the drilling operation. A method for monitoring and recording of the drilling operation wherein a drill string having a kelly and a drill bit is turned by means of a rotary motor.

2 Claims, 5 Drawing Figures



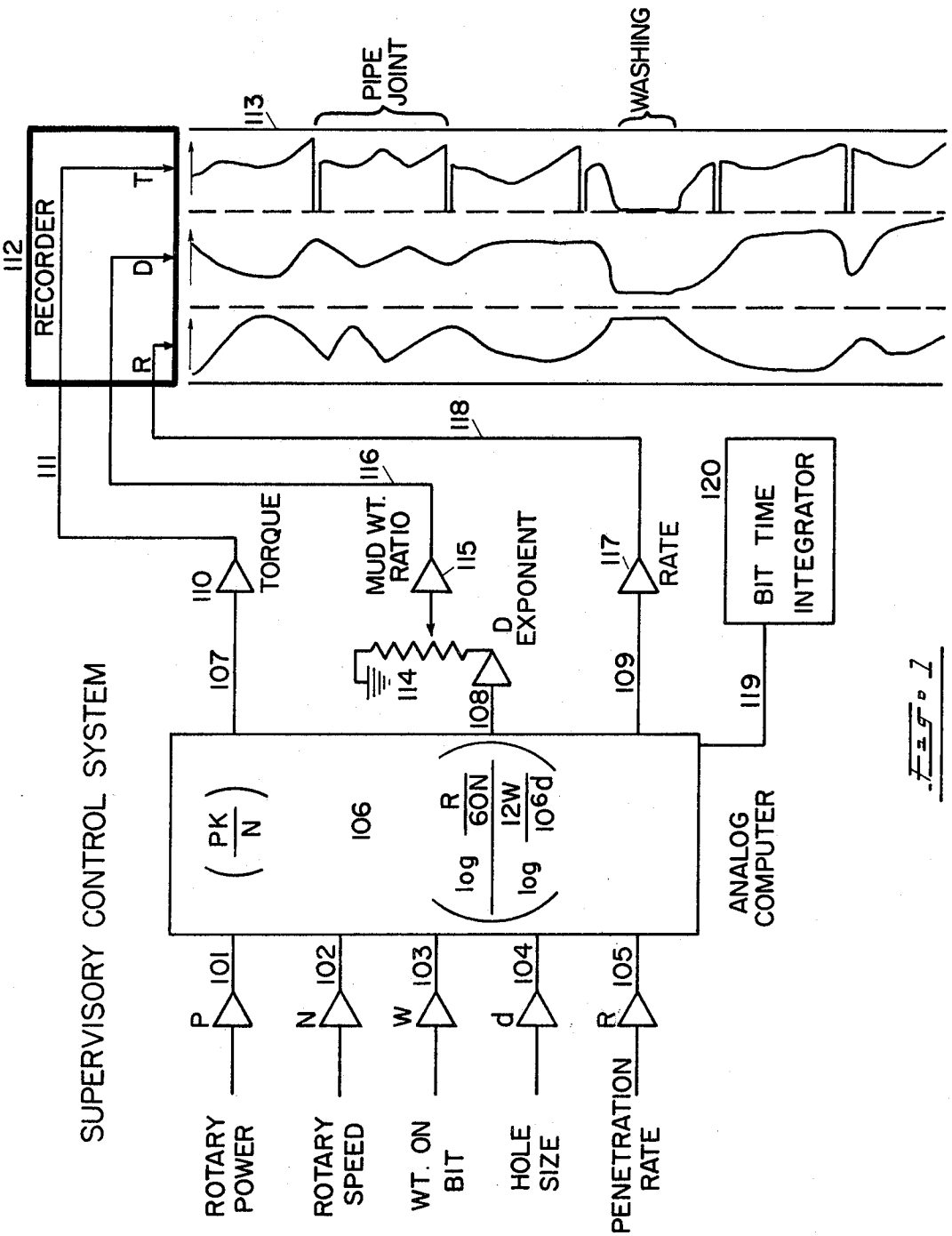

SUPERVISORY CONTROL SYSTEM
ROTARY POWER
ROTARY SPEED
WT. ON BIT
HOLE SIZE
PENETRATION RATE
P 101
N 102
W 103
d 104
R 105
106
ANALOG COMPUTER
TORQUE
MUD WT. RATIO
D EXPONENT
RATE
BIT TIME INTEGRATOR
107
108
109
110
111
112
RECORDER
T
D
R
113
PIPE JOINT
WASHING
114
115
116
117
118
119
120

Fig. 1

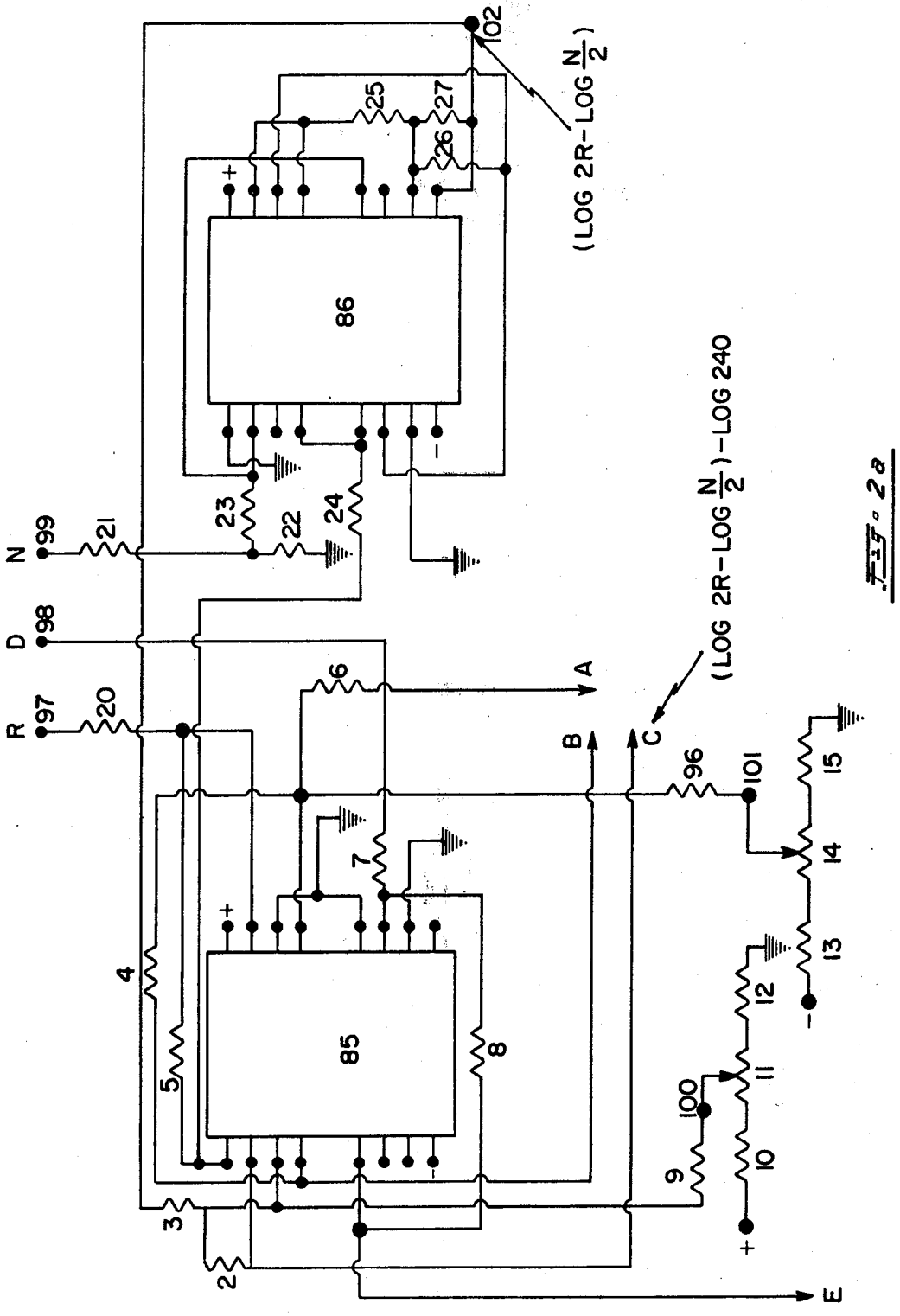

102
(LOG 2R-LOG N/2)
25
27
26
86
23
22
24
N
99
21
D
98
R
97
20
6
A
B
C
(LOG 2R-LOG N/2)-LOG 240
96
101
15
14
13
12
11
100
10
9
7
4
5
85
8
3
2
+
-
E

FIG. 2a

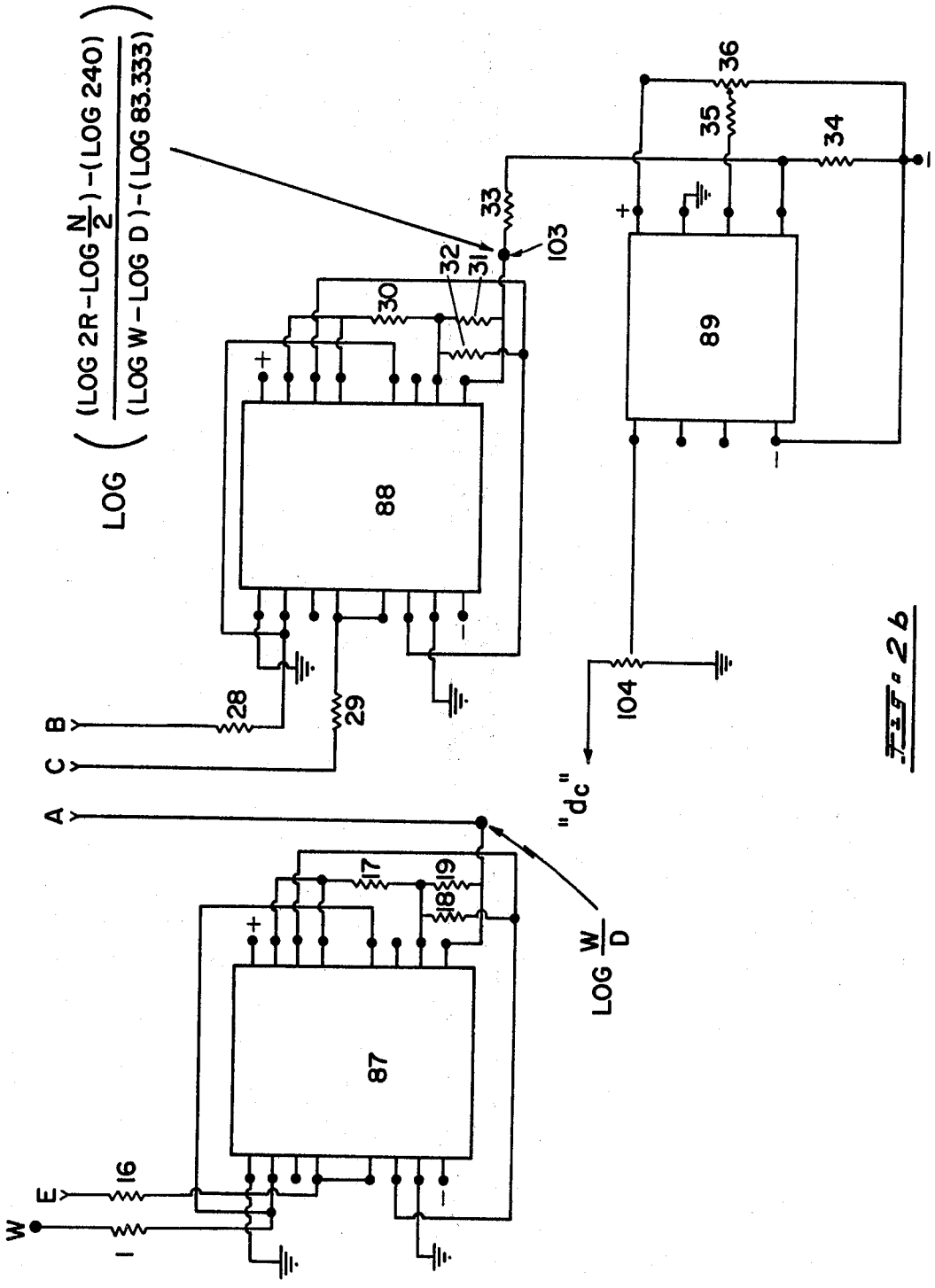

LOG ((LOG 2R − LOG N/2) − (LOG 240)) / ((LOG W − LOG D) − (LOG 83.333))
W
E
I
16
87
17
18
19
LOG W/D
A
B
C
28
29
88
30
31
32
33
103
"dc"
104
89
34
35
36

FIG. 26

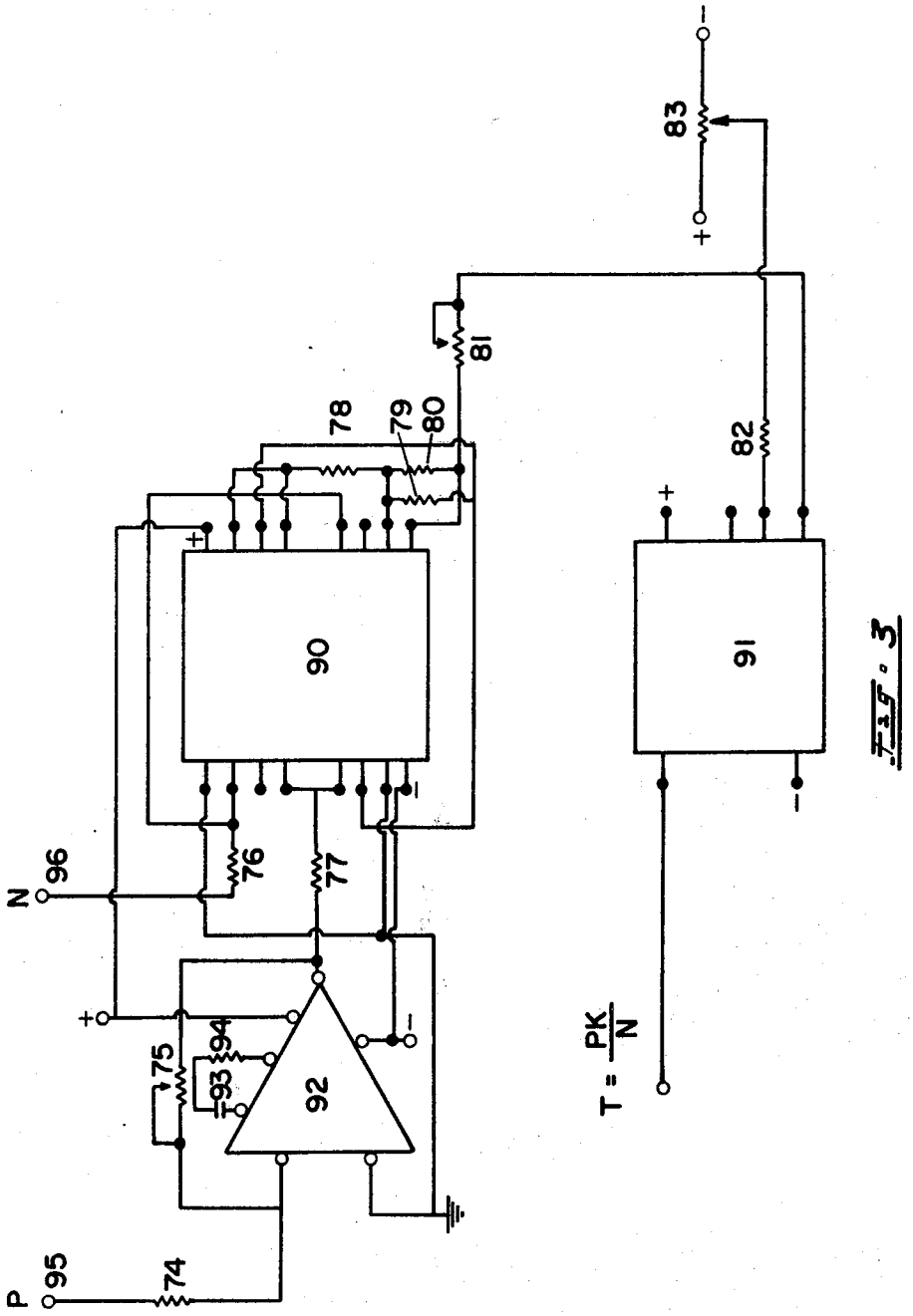


FIG. 3

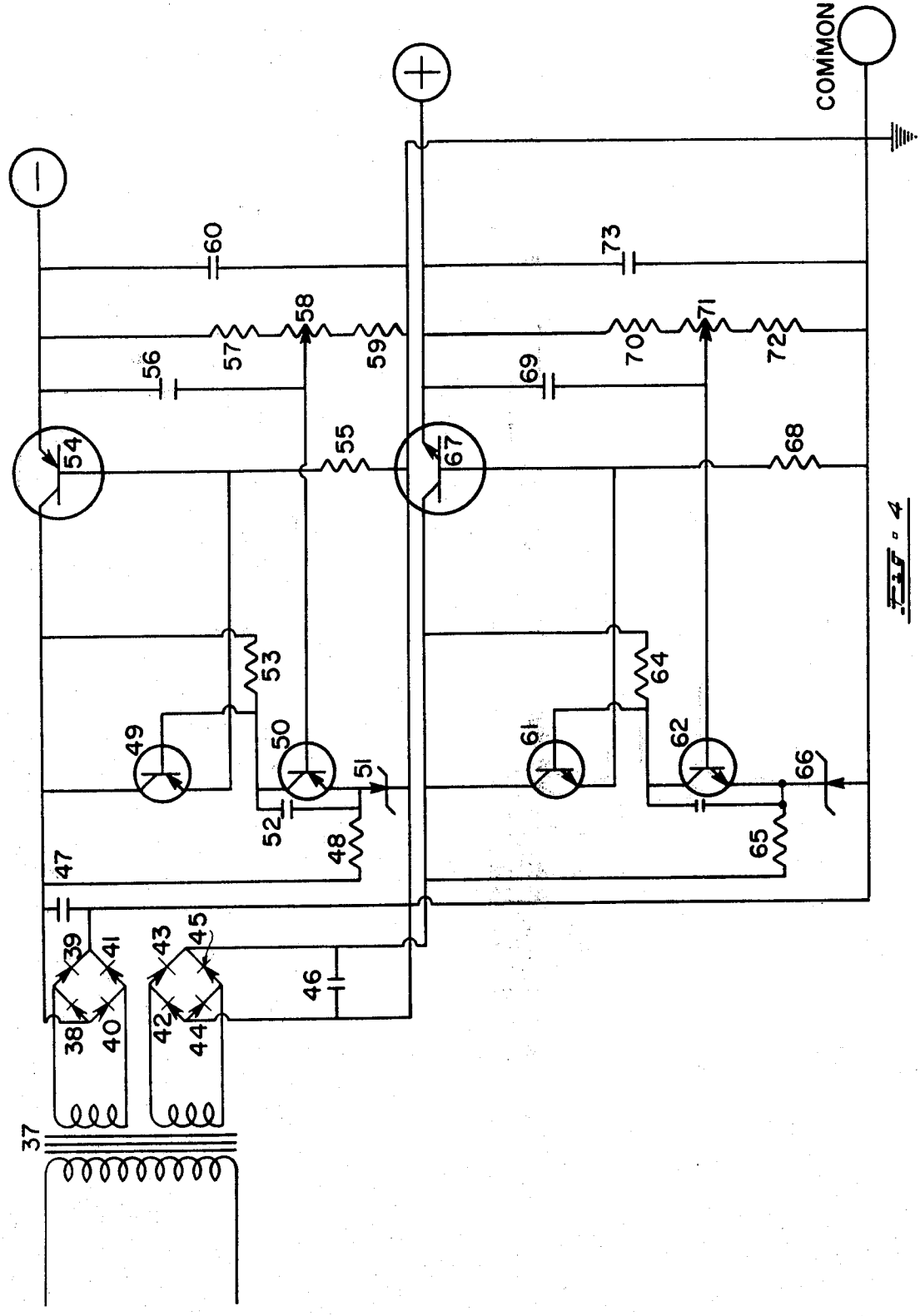

COMMON
60
73
58
71
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59
70
72
56
69
54
55
67
68
53
64
49
50
61
62
66
51
52
48
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47
39
41
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38
40
42
44
37

FIG. 4

ELECTRONIC SUPERVISORY MONITORING METHOD FOR DRILLING WELLS

This is a continuation application of our copending application, Ser. No. 335,191, filed Feb. 23, 1973, now abandoned, which was a continuation-in-part application of U.S. Pat. No. 3,785,202, patented Jan. 15, 1974 (formerly patent application having Ser. No. 156,645, filed June 25, 1971).

This invention relates to a method for supervisory control during the drilling of wells. More particularly, the method of the present invention is an electronic supervisory control system for monitoring various drilling variables and through electronic manipulation of these variables obtaining useful information for the control and observation of the drilling operation.

In applying technology to a drilling operation, it is often a requisite criteria that one obtain a general concept and preferably an exact knowledge of the presence and lithology of formations being encountered or to be encountered by the drilling bit. Various and sundry methods have been proposed for prediction of formations to be encountered or for alarm systems for detecting when a drill bit enters certain formations. In particular, a patent to Jordon, et al., U.S. Pat. No. 3,368,400, METHOD FOR DETERMINING THE TOP OF ABNORMAL FORMATION PRESSURES, teaches a process for detecting when a bore hole enters a geopressured shale section, utilizing the penetration rate of the drill bit as the measured variable. The penetration rate of the drill bit is applied over shale sections, to determine the rate of change in penetration rate as the drill bit enters the top of a geopressured shale. The top of the geopressure section is detected by locating the depth at which the rate of change in the rate of penetration distinctly changes. Therefore, through the teaching of Jordon and a determination of the penetration rate, one finds a tool for determining the exact location and depth of the geopressured shale sections so that mud weights and drilling variables may be changed to anticipate well blowouts.

Brown, et al., U.S. Pat. No. 3,541,852, ELECTRONIC SYSTEM FOR MONITORING DRILLING CONDITIONS RELATING TO OIL AND GAS WELLS, teaches the recordation of information by a system, including drilling depth, time, penetration rate, hook load, rotary speed, pump strokes, gas chromatography, and such drilling mud information as weight in-weight out, viscosity, temperature, and flow rates. These data are utilized with the monitoring of drilling rig variables, (for example total depth, rate of penetration, and speed of rotation of the drill bit) to provide a new system for monitoring the rate of penetration of a drill bit used in drilling an oil and gas well.

None of the disclosed prior art have shown a system and a method for the supervisory control of the entire drilling operation where it is particularly advantageous at all times to realize the lithology of the formations being penetrated by a drill bit, and to particularly understand and control the drilling operation through a knowledge of the lithology being penetrated. What is required is a method for determining in any time period during a drilling operation that lithology which is being encountered by the drill bit or will be encountered a considerable distance ahead of the drill bit. In conjunction with the method are means for monitoring and controlling the drilling variables in order that hazardous conditions may be avoided along with the curtailment of blowouts and other catastrophies.

It is an object of the present invention to provide means for determining the lithological nature of formation encountered by a drill bit.

It is a further object of the present invention to provide means for the supervisory control of a drilling operation.

It is still a further object of the present invention to provide means and a method for monitoring, recording and supervisory control of a drilling operation through the measurement of specific drilling variables.

With these and other objects in mind, the present invention may be more fully understood through referral to the accompanying drawings and following description.

SUMMARY OF THE INVENTION

The objects of the present invention may be accomplished through an electronic supervisory control system for monitoring and recording of a drilling operation. The electronic supervisory control system comprises computer means for computing, means for sensing the rotary motor power, means for sensing the rotary motor speed, means for sensing the weight on the drill bit, and means for sensing the penetration rate of the drill bit. The means for sensing the weight on the drill bit and the means for sensing the penetration rate of the drill bit are utilized in combination with a determination of the drilled hole size and mud weight ratios to compute a corrected *d* exponent. The means for sensing the rotary motor power and the means for sensing the rotary motor speed are utilized to compute a rotary motor torque. The computed *d* exponent, rotary motor torque and rate of penetration are simultaneously plotted on an electronic recorder as a function of actual drilled depth.

The electronic supervisory control system of of the present invention may further comprise a bit time integrator for recording operational drilling time utilized in conjunction with the sensor data recording. Other preferred embodiments of the present invention also comprise the combination of the rotary motor power electrical signal with an electrical signal from the bit time integrator to produce a bit wear and exposure electrical signal, and the combination of the rotary motor power electrical signal with the rate of penetration electrical signal to produce an energy expended per depth interval electrical signal. The bit wear and exposure electrical signal and energy expended for depth electrical signal may also be plotted on an electronic recorder to give exacting monitoring of the drilling operation and allow for the supervisory control thereof.

The method for monitoring and recording of a drilling operation wherein a drill string having a kelly and a drill bit is turned by means of a rotary motor comprises inputting a drilled hole size and a mud weight ratio into a computer means for computing, and sensing each of the rotary motor power, the rotary motor speed, the weight on the drill bit and the penetration of the drill bit and feeding the sensed value of each into the computer means as an electrical signal. The method additionally includes computing by the computer means a corrected *d* exponent from the weight on the drill bit, the penetration rate of the drill bit, the drilled hole size, and the mud weight ratio based upon the signaled value of each as fed into the computer means,

and simultaneously computing by the computer means a rotary motor torque from the signal values of the rotary motor speed and the rotary motor power as are fed into the computer means; and feeding the corrected *d* exponent and the rotary motor torque from the computer means into means for recording where each is recorded along with the rate of penetration of the bit.

BRIEF DESCRIPTION OF THE DRAWING

The present invention may be more fully understood by referral to the accompanying drawings in which:

FIG. 1 schematically illustrates the preferred embodiment of the supervisory control system of the present invention with various sensors utilized and the recorded output provided;

FIGS. 2*a* and 2*b* represent an electronic schematic of one embodiment of the analog computer utilized in the present invention in order to compute a corrected *d* exponent for monitoring and supervisory control of the drilling operation;

FIG. 3 represents an analog schematic of one embodiment of an analog computer circuit utilized in order to compute the torque of the rotary table and drill string utilized for recordation in the supervisory control system of the present invention; and

FIG. 4 represents an electronic schematic of one embodiment of a power supply utilized in the supervisory control system of the present invention.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

The present invention may be most easily understood by referral to the FIG. 1 in which the electronic supervisory control system of the present invention is depicted in a schematic representation. It can be readily seen that the supervisory control system consists of the sensing of various drilling variables of the drilling operation, comprising in particular rotary power, rotary speed, weight on drill bit and drill string, drill hole size, and penetration rate in conjunction with a mud weight ratio.

In general, it may be stated that these drilling operation variables are sensed by means for sensing the drilling variables. In particular, the computer means for computing is preferably an analog computer. The means for sensing the rotary motor power is electrically connected to the computer means and may comprise a rotary motor power sensor mounted upon the shaft of the rotary motor in conjunction with means for converting the rotary motion of the shaft measured by the rotary motor power sensor to an electrical signal and electrical circuit means to transmit the electrical signal from the rotary motor power sensor to the other portions of the electronic supervisory control system. Alternatively, the means for sensing the rotary motor power may comprise an electrical rotary motor power sensor connected to the power line of the rotary motor in conjunction with an electrical circuit means to transmit an electrical signal from the electrical rotary motor power sensor. The means for sensing the rotary motor speed is electrically connected to the computer means and may comprise an electrical rotation sensor connected to the drill string or kelly of the drilling rig and an electrical circuit means to transmit an electrical signal from the electrical rotation sensor to other portions of the electronic supervisory control system. In further respect, the means for sensing the weight on the drill bit is electrically connected to the computer means and may comprise an electrical powered drill bit and drill string weight sensor and electrical circuit means to transmit an electrical signal from the electrical drill bit and drill string weight sensor. In particular, the drill bit and drill string weight sensor may comprise a tension spring connected from the kelly to the drill string, having responsive electrical stops thereupon to convert the flexing of the mechanical spring into an electrical signal which is transmitted to the electronic supervisory control system. Similarly, the means for sensing the penetration rate of the drill bit is electrically connected to the computer means and may comprise an electrical rotation sensor connected to the rotary table and an electrical depth sensor connected to the drill string, to measure vertical movement of the drill string, with means for integrating the electrical signals from the electrical rotary table rotation sensor and electrical depth sensor to produce a rate of penetration electrical signal. An electrical circuit means is provided to transmit the rate of penetration electrical signal to the electronic supervisory control system.

Means are provided for inputting a drilled hole size into the computer means. The drilled hole size may be manually measured and fed through a potentiometric electronic indicator into the supervisory control system, or it may actually be measured through electronic sensors contained within the drill bit or drill string with appropriate electronic potentiometric circuit means to transmit the electrieal signal from the sensors to the supervisory control system. Means are also provided for inputting a mud weight ratio into the computer means. The mud weight ratio may be measured by the electronic measurement of mut pit sensors showing the change in mud weight-in versus mud weight-out of the wellbore or in a preferred embodiment, the normal gradient for the mud density in the geographical area of the well being drilled may be utilized in conjunction with the returned mud weight in order to derive the mud weight ratio utilized in combination with the potentiometric signal of the weight on the bit, the predetermined hole size, and the electrical signal of penetration rate in order to compute a *d* exponent value. Means for recording is electrically connected to the computer means for recording computed values and penetration rate, and is preferably a depth driven electronic recorder.

The method for monitoring and recording of the drilling operation initially provides for inputting the drilled hole size and the mud weight ratio into a computer. Subsequently, the rotary motor power, the rotary motor speed, the weight on the drill bit, and the penetration rate of the drill bit are sensed and fed to the computer as electrical signals. The method further calls for the computer to compute a corrected *d* exponent from the weight on the drill bit, the penetration rate of the drill bit, the drilled hole size, and the mud weight ratio based upon the signaled value of each as it is fed to the computer. Simultaneously, the computer computes a rotary motor torque from the signal values of the rotary motor speed and the rotary motor power as they are fed into the computer. The final step for monitoring and recording of the drilling operation is the feeding of the corrected *d* exponent and the rotary motor torque from the computer into means for recording where each is recorded along with the rate of penetration of the bit.

Therefore, in the supervisory control system, the various components of rotary power, rotary speed, weight on the drill bit, hole size, and penetration rate are introduced into a buffer system of the supervisory control system. The amplifiers are depicted in FIG. **1** as rotary power-buffer amplifier **101**, rotary speed-buffer amplifier **104** and penetration rate-buffer amplifier **105**. The amplifiers are utilized to convert the electrical signals to those signals required for the computation of the various drilling indicators. These drilling indicators are computed within an analog computer **106** in which the electrical signal for torque of the drilling operation, which represents the rotary power times a predetermined constant divided by the rotary speed, is produced through electrical circuit **107**. The *d* exponent is an empirical exponent represented by the following equation;

$$d = \frac{\log\left(\frac{R}{60N}\right)}{\log\left(\frac{12\,W}{10^6 D}\right)}$$

wherein

R = rate of penetration, feet per hour

N = rotary speed, revolutions per minute

W = weight on drill bit, pounds

D = drill bit diameter, inches

The numerator computed portion of the *d* exponent is calculated by taking the natural logarithm of the penetration rate divided by the rotary speed times 60 (in order to convert to hours). The denominator computed portion of the *d* exponent is calculated by taking the natural logarithm of 12 times the weight on the drill bit and drill string divided by 10^6 times the hole size (in order to reduce to feet). Dividing the numerator computed portion by the denominator computed portion produces an electrical signal for the *d* exponent, which is transmitted through electrical circuit **108**. A penetration rate signal is produced through electrical circuit **109**. The computed torque signal is fed to a driver gain amplifier **110** through electrical circuit **107** to transmit an appropriate electrical signal through electrical circuit **111** to be received by the recorder **112** and plotted on a strip chart **113**. The display of this signal is indicative of various operations, shown on the synthetic trace, such as a pipe jointing operation and washing operation. The computed *d* exponent signal produced through circuit **108** is fed to gain amplifier **115** which works through a potentiometer **114** having the mud weight ratio programmed therein to form a system which yields a corrected *d* exponent signal which is subsequently fed through electric circuit means **116** to the recorder **112** in order to be recorded on the strip chart **113**. Similarly, the rate of penetration signal is also fed through electrical circuit **109** to gain amplifier **117** to transmit an appropriate electrical signal through electrical circuit **118** to be recorded on the strip chart **113** by the recorder **112**.

A continuous monitoring of rate of penetration, *d* exponent, and rotary torque is given for the drilling operation by the electrical log of these various drilling operations provided by the supervisory control system of the present invention. In conjunction with the present apparatus, an electrical signal of finite time may be fed through electric circuit **119** to a bit time integrator **120** in order to record actual drilling time of the operation shown on the depth drive recorder **112**.

FIG. **2**, which embodies FIG. **2***a* and FIG. **2***b*, typifies the analog computer circuitry utilized in order to compute the corrected *d* exponent value from the electrical signals of rotary speed, N, weight-on the drill bit and drill string, W, hole size, D, penetration rate, R, and mud weight ratio. The various components of the analog circuitry are comprised of the major amplifier sections shown in detail with the various and sundry resistors, capacitors, voltage inputs and circuitry depicted and numbered accordingly with each of the values of the component parts corresponding to those illustrated in FIGS. **2***a* and **2***b* shown in the following Table I:

TABLE I

Component Number	Value
1	10,000 ohms, 1/2 watt, 1%
2	10,000 ohms, 1/2 watt, 1%
3	10,000 ohms, 1/2 watt, 1%
4	10,000 ohms, 1/2 watt, 1%
5	20,000 ohms, 1/2 watt, 1%
6	10,000 ohms, 1/2 watt, 1%
7	10,000 ohms, 1/2 watt, 1%
8	10,000 ohms, 1/2 watt, 1%
9	10,000 ohms, 1/2 watt, 1%
10	2,700 ohms, 1/2 watt, 5%
11	200 ohms, potentiometer
12	510 ohms, 1/2 watt, 5%
13	3,600 ohms, 1/2 watt, 5%
14	200 ohms, potentionieter
15	510 ohms, 1/2 watt, 5%
16	10,000 ohms, 1/2 watt, 1%
17	6,200 ohms, 1/4 watt, 5%
18	6,200 ohms, 1/4 watt, 5%
19	100,000 ohms, 1/4 watt, 5%
20	10,000 ohms, 1/2 watt, 1%
21	5,000 ohms, 1/2 watt, 1%
22	5,000 ohms, 1/2 watt, 1%
23	10,000 ohms, 1/2 watt, 1%
24	10,000 ohms, 1/2 watt, 1%
25	6,200 ohms, 1/4 watt, 5%
26	6,200 ohms, 1/4 watt, 5%
27	100,000 ohms, 1/4 watt, 5%
28	10,000 ohms, 1/2 watt, 1%
29	10,000 ohms, 1/2 watt, 1%
30	6,200 ohms, 1/4 watt, 5%
31	100,000 ohms, 1/4 watt, 5%
32	6,200 ohms, 1/4 watt, 5%
33	5,100 ohms, 1/2 watt, 5%
34	100,000 ohms, 1/4 watt, 5%
35	82,000 ohms, 1/2 watt, 5%
36	10,000 ohms, potentiometer
85	9432 monolithic op amps. (5) O.E.I.
86	2457 monolithic universal logarithmic module O.E.I.
87	2457 monolithic universal logarithmic module O.E.I.
88	2457 monolithic universal logarithmic module O.E.I.
89	395 anti-logarithmic module O.E.I.
136	10,000 ohms potentiometer

Referring to FIG. **2***a* which schematically illustrates the circuitry for a partial solution of the equation

$$d = \frac{\log\left(\frac{R}{60N}\right)}{\log\left(\frac{12W}{10^6 D}\right)}$$

The electronic solution requires scaling of the original equation to restrict the electrical values to be within the dynamic range of the electronic modules. The scaled equation is:

$$\left(\frac{\left(\log 2R - \log \frac{N}{2}\right) - (\log 240)}{\log W - \log D - (\log 83.333)}\right)$$

The solution for the numerator log 2R − log N/2 − (log 240)
is schematically illustrated by FIG. 2*a*.

It should be appreciated that with this particular type of operational amplifier module **85** there are five operational amplifiers enclosed within module **85.** These are available through Optical Electronics, Inc., in Tucson, Arizona and are identified as amplifier module **9,432.**

FIG. 2*a* shows electrical input R **97** coupled through input resistor **20** to the inverting input of an operational amplifier having a fixed gain of two, developed by feedback resistor **5** being coupled from inverting input to output. This output is representative of inverted **2** R in the equation and is coupled through resistor **24** to the input of the logarithmic amplifier module **86.**

Looking at input N **99,** an electrical input is connected to a balanced voltage divider. The junction voltage between resistors **21** and **22** is equal to N/2 and coupled to the input of another logarithmic amplifier contained in module **86** through resistor **23.** The outputs of the two logarithmic amplifiers are connected to resistors **25** and **26** which together comprise a summing junction that is connected to the inverting input of an operational amplifier also included in module **86.** The gain of this amplifier is adjusted by feedback resistor **27** to cause the output at junction **202** of this amplifier to be the electrical representation of (log 2 R − log N/2). The junction **202** is coupled back to an operational amplifier contained in module **85** through resistor **3** to the inverting input. Also coupled to this inverting input through resistor **9** and adjusted by potentiometer **11** is a voltage equal to 2.38 volts which represents the log of 240. The junction of input summing resistors **3** and **9** is connected to the inverting input of an operational amplifier in module **85** and resistor **2** connected from output to inverting input sets the gain at one. This output is shown at point C on FIG. 2*a* and is the electrical representation of

$$\left(\log 2R - \log \frac{N}{2}\right) - (\log 240).$$

Referring again to FIG. 2*a* and to the denominator portion of the scaled equation (log W − log D) − (log **83.333**) and electrical input, D **98** is shown connected to the inverting input of another operational amplifier of module **85** through input resistor **7.** The output of this amplifier is coupled back to the input through feedback resistor **8** which sets the gain at one. The output shown as point E on FIG. 2*a* is also shown as point E of FIG. 2*b*.

Referring now to FIG. 2*b*, there is illustrated circuitry for solving the remaining portion of the equation:

$$\frac{\left(\log 2R - \log \frac{N}{2}\right) - (\log 240)}{(\log W - \log D) - (\log 83.333)}$$

Point E is representative of D in the equation and is shown connected to the input of a logarithmic amplifier of module **87** through resistor **16.** Point W is representative of W in the equation and is shown connected through resistor **1** to another logarithmic amplifier of module **87.** The outputs of these log amplifiers are connected to the input of an operational amplifier in module **87** through summing resistors **17** and **18.** The gain of this amplifier is fixed by feedback resistor **19** to be the electrical representation of (log W − log D) in the equation. Referring back to FIG. 2*a* at point **201,** a voltage of − 1.92 volts [the electrical representation of −(log 83.333)], is adjusted by potentiometer **14** and connected through resistor **96** to the inverting input of an operational amplifier again contained in module **85.** Point A on FIG. 2b is the electrical output representing (log W − log D) and it is shown on FIG. 2*a* as point A connected through resistor **6** to the junction of resistor **96.** This provides a summing junction for the operational amplifier input. The gain of this amplifier is fixed by feedback resistor **4** coupled from output to inverting input. The output voltage of this operational amplifier **85** is the sum of (log W − log D) − (log 83.333). This concludes the solution for the denominator portion of the scaled equation and this portion of the equation is represented on FIG. 2*a* and FIG. 2*b* as point B.

Referring to FIG. 2*b*, point B is connected through resistor **28** to the input of a logarithmic amplifier contained in module **88.** Point C is connected to the input of a second logarithmic amplifier in module **88** through resistor **29.** Note that point B is the electrical solution of (log W − log D) − (log 83.333) and point C is the solution of

$$\left(\log 2R - \log \frac{N}{2}\right) - (\log 240).$$

The next logarithmic amplifier in module **88** is utilized to divide point C by point B. Point C is divided by point B by subtraction of log point B from log point C. The output of the logarithmic amplifier producing log point B is connected through resistor **30** to the input of an operational amplifier contained in module **88.** The output of the logarithmic amplifier producing log C is connected through resistor **32** to the same input junction as resistor **30.** The voltage of log C is of opposite polarity to that of log B and the output of the operational amplifier **203** will be a voltage representing the logarithm of log C − log B. At the point **203** of FIG. 2b the scaled equation has been electrically solved to a point where we have:

$$\log \frac{\left(\log 2R - \log \frac{N}{2}\right) - (\log 240)}{(\log W - \log D) - (\log 83.333)}$$

and the scaled equation for log D is:

$$d = -\frac{\left(\log 2R - \log \frac{N}{2}\right) - (\log 240)}{(\log W - \log D) - (\log 83.333)}$$

By taking the anti-log of point **203** the equation is solved. Point **203** is connected through resistor **33** to the input of anti-logarithmic amplifier **89.** The output of **89** is adjusted to the proper level by potentiometer **36** and offset resistor **34** to give a voltage output that is equal to the anti-log of the input voltage. This output voltage is then applied to potentiometer **204** which is set as a voltage divider proportional to the ratio of normal mud weight used in a particular area (region) to

the measured mud weight actually being used in the drilling operation.

It should be understood that many of the component parts of the apparatus used in this invention must be carefully selected to minimize error and that the selected values for electrical components used in specific embodiments such as those described herein, may be critical to proper operation of the apparatus.

Referring to FIG. 3, the analog circuitry utilized for computing the torque T for recordation from the electrical signals of rotary speed N, rotary power P and the predetermined constant K is depicted with the following Table II listing the values and component parts corresponding to the illustrated FIG. 3.

TABLE II

Component Number	Value
74	10,000 ohms, ½ watt, 1%
75	10,000 ohms, potentiometer "K" input
76	10,000 ohms, ½ watt, 1%
77	10,000 ohms, ½ watt, 1%
78	6,200 ohms, ¼ watt, 5%
79	6,200 ohms, ¼ watt, 5%
80	100,000 ohms, ¼ watt, 5%
81	10,000 ohms, potentiometer
82	15,000 ohms, ½ watt, 5%
83	10,000 ohms, potentiometer
90	2457 Optical Electronics, Inc. logarithmic module
91	395 Optical Electronics, Inc. anti-logarithmic module
92	709 operational amplifier
93	.001 mf, 50 volt condenser
94	1,500 ohms, ½ watt, 5%
295	rotary power input
296	R.P.M. input
T	torque output

The electrical signal representinig rotary power P is obtained from junction **295** and is coupled to the inverting input of operational amplifier **92** through resistor **74.** The gain of amplifier **92** is adjustable to a gain of one or less by the connection of variable resistor **75** coupled from the output to the inverting input. The variable resistor **75** also represents the constant K. The output voltage of amplifier **92** will be the inverted product of electrical signal input P times the predetermined constant K. The output of amplifier **92** is coupled to the input of a logarithmic amplifier contained in the monolithic module **90** through resistor **77.** The electrical signal representing rotary speed N is obtained from junction **296** and is coupled to a second logarithmic amplifier contained in module **90** through resistor **76.** The inputs of these two logarithmic amplifiers are of opposite polarity. The outputs of the two logarithmic amplifiers are coupled to an amplifier input through the summing resistors **78** and **79.** The output of the module amplifier **90** is a voltage representative of log PK-log N. The output of module **90** is coupled to an anti-log module **91** through trimming potentiometer **81.** Potentiometer **83** is used as offset and trimming of the anti-log module. The anti-log of the difference between log PK and log N is arithmetically equal to PK divided by N, or PK/N. Proper ajdustment of potentiometers **81** and **83** will result in an electrical voltage output of anti-log module **91** that is representative of Torque when the equation Torque = PK/N is considered.

FIG. 4 is a typical schematic representative of any "off-the-shelf" well-filtered, well-regulated, directcurrent power supply adjustable to plus and minus **13.3** volts. The various components depicted in FIG. 4 are listed in Table III giving the values of the components of FIG. 4 as enumerated.

TABLE III

Component Number	Value
37	120 volt, 60 Hz primary, dual secondary 15 volts each
38	1 amp silicon rectifier GE 509
39	1 amp silicon rectifier GE 509
40	1 amp silicon rectifier GE 509
41	1 amp silicon rectifier GE 509
42	1 amp silicon rectifier GE 509
43	1 amp silicon rectifier GE 509
44	1 amp silicon rectifier GE 509
45	1 amp silicon rectifier GE 509
46	100 mf 50 volt condenser
47	100 mf 50 volt condenser
48	2,200 ohms 5%, ½ watt
49, 61	2N1305 Transistor
50, 62	2N1305 Transistor
51	12 volt, 1 watt Zener diode
52	.001 mf condenser
53	5,100 ohms 5%, ½ watt
54	GE 3 Transistor
55	6,800 ohms 5%, ½ watt
56	50 mf 50 volt condenser
57	1,500 ohms 5%, ½ watt
58	2,000 ohms potentiometer
59	250 ohms 5%, ½ watt
60	100 mf 50 volt condenser
63	.001 mf condenser
64	5,000 ohms 5%, ½ watt
65	2,200 ohms 5%, ½ watt
66	12 volt, 1 watt Zener diode
68	6,800 ohms 5%, ½ watt
69	50 mf 50 volt condenser
70	1,500 ohms 5%, ½ watt
71	2,000 ohms potentiometer
72	250 ohms 5%, ½ watt
73	100 mf 50 volt condenser

Therefore, through the various sensors described herein, it can be seen how the supervisory control system may be utilized in order to convert electrical signals from the electronic sensors into useful supervisory control data for both monitoring and use with other systems. The simulated chart on FIG. 1 depicts a typical recording of rate of penetration, corrected *d* exponent and torque for use in order to control the actual drilling operation such that the drilling operator is afforded a greater continuous recording of drilling information and the opportunity to store the data and utilize it further for optimal drilling and prevention of catastrophies.

While the invention as has been described above with respect to certain embodiments thereof, it will be understood by those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the invention as set forth herein.

Therefore, we claim:

1. A method for monitoring and recording of a drilling operation wherein a drill string having a kelly and a drill bit is turned by means of a rotary motor, said method comprising:

a. inputting a drilled hole size and a mud weight ratio into a computer means for computing;

b. sensing each of the rotary motor power, the rotary motor speed, the weight on the drill bit and the penetration rate of the drill bit and feeding the sensed value of each into said computer means as an electrical signal;

c. computing by said computer means a corrected *d* exponent from said weight on the drill bit, said penetration rate of the drill bit, said drilled hole size,

and said mud weight ratio based upon the signaled value of each as fed into said computer means and simultaneously computing by said computer means a rotary motor torque from the signal values of said rotary motor speed and said rotary motor power as are fed into said computer means;

d. feeding said corrected *d* exponent and said rotary motor torque from said computer means into means for recording where each is recorded along with said rate of penetration of the bit.

2. Method of monitoring and recording a drilling operation wherein a well hole is drilled by means of a drill bit turned with a rotary motor, said method comprising:

a. inputting a drilled hole size and a mud weight ratio into a computer,

b. sensing each of the rotary motor power, the rotary motor speed, the weight on the drill bit and the penetration rate of the drill bit and feeding the sensed value of each into said computer as an electric signal,

c. computing a corrected D exponent from weight on the drill bit, penetration rate of the bit, drilled hole size and the mud weight ratio based upon the signaled value of each as fed into the computer, and simultaneously computing the rotary motor torque from the signal values of motor speed and motor power as are fed into the computer, and

d. feeding corrected D exponent and rotary motor torque out of the computer and recording the value of each while also recording the penetration rate of the bit.

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