PATENT SPECIFICATION (11) 1 583 393

1 583 393

(21) Application No. 29422/77 (22) Filed 13 Jul. 1977 (19)
(31) Convention Application No. 711297 (32) Filed 3 Aug. 1976 in
(33) United States of America (US)
(44) Complete Specification Published 28 Jan. 1981
(51) INT. CL.[3] G01F 23/18
G01N 9/26
(52) Index at Acceptance
G1H 3
G1S 7S

(54) METHOD AND APPARATUS FOR MEASURING VOLUME AND DENSITY OF FLUIDS IN A DRILLING FLUID SYSTEM

(71) We, BAILEY MUD MONITORS INC. a Corporation organised and existing under the laws of the State of Louisiana, United States of America, of First Federal Building, Thibodaux, State of Louisiana 70301, 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:-

Since it is well established that blowouts, sub-surface structure damage, costly breakdowns with stuck pipe, and several other undesirable side-effects are directly associated with the drilling fluid (mud) circulation system in drilling a well, a method and apparatus for providing essential and accurate fluid systems data will be of great use and service to the industry and the art. By the very nature of drilling fluids, (drilling mud) as is well known by those familiar with the art, densities are continually changing, foreign materials and particles are constantly introduced into the system, and those fluid measuring devices presently in use have moving parts which are designed to come into actual physical contact with the drilling fluids during their operation. For example, fluid pit floats, which measure pit levels must float on the drilling fluids to operate and frequently they indicate different levels merely on change of fluid densities regardless of actual level changes. Pump stroke counters, which measure piston displacement are accurate only to the degree of pump efficiency and most pumps that have been used in the field for any period of time have varying reduced efficiencies. Flow meters are some times affected by foreign particles and have been known to produce inaccurate results. Volumetric accuracies to minimal tolerances are especially desirable in detecting a so called "kick" (incursion of gases and/or formation fluids down-hole) inasmuch as the rate of gas expansion from bottom hole to surface is exponentially increased so that a volume of one barrel at the bottom of the hole might increase to hundreds of barrels at the surface.

Because of the infinite variety of fluid conditions encountered in drilling a well, it is suggested that those devices presently used for measuring drilling mud volumes, all of which have moving parts coming into contact with the fluid itself, have inherent inaccuracies which at times exceed tolerable parameters, and therefore it is desirable to provide a method and apparatus which can accomplish the measurement of drilling fluid volume and densities without the necessity of having any moving parts coming into contact with the fluid itself. It is also desirable that drilling fluid volumes can be indicated independent of their densities and conversely that densities can be indicated independently of volume. It is desirable that accuracies of less than one barrel pit volume change and 0.075 lb./gallon mud density change be achieved in order to fall within tolerable parameters.

The invention provides a method of measuring volume and density of mud in a mud pit in a drilling fluid system comprising the steps of:

a) providing a first means for measuring pressure in a mud pit at a first position a fixed distance above the bottom of the pit;

b) providing a second means for measuring pressure in the mud pit at a second position a fixed distance above the first position;

c) connecting a first device to the first and second means to produce a signal proportional to the difference in pressures measured by the first and second means;

d) connecting a second device to the first means to produce a signal proportional to the pressure measured by the first means;

e) introducing the signals from the first and second devices as an input to a dividing bridge;

f) introducing the signal from the first device to a gauge displaying a reading of mud density;

g) communicating the output signal of the dividing bridge through a biasing relay to add a constant for the distance above the bottom of the mud pit of the first position at which pressure is measured by the first means, the output of the biasing relay representing the volume of the mud in the pit.

The invention provides an apparatus for measuring volume and density of mud in a mud pit in a drilling fluid system comprising:

a) a first means for measuring pressure in a mud pit at a first position a fixed distance above the bottom of the pit;

b) a second means for measuring pressure in the mud pit at a second position a fixed distance above the first position:

c) a first device connected to the first and second means for producing a signal proportional to the difference in pressures measured by the first and second means;

d) a second device connected to the first means for producing a signal proportional to the pressure measured by the first means;

e) a dividing bridge receiving the signals from the first and second devices;

f) a gauge receiving and displaying a reading proportional to the signal from the first device;

g) a biasing relay receiving the signal from the dividing bridge and adding a constant thereto; and

h) a gauge receiving and displaying a reading proportional to the signal from the biasing relay.

An embodiment of the invention will be described hereinafter and with reference to the accompanying drawings, in which like parts are denoted by reference characters throughout the several views:

Figure 1 is a diagrammatic view of the mud density and volume measuring apparatus of the present invention applied to a single mud pit;

Figure 2 is a schematic of the inputs from a plurality of mud pits showing total barrels of mud in pits and a gain or loss indicator together with a 24 hour record; and

Figure 3 is a diagrammatic view of the system of Figure 1 applied to three mud pits and the "Possum Belly".

This invention provides an accurate method and apparatus for measuring volume and density of fluids in a drilling fluid system. It more specifically provides these measurements at all times during the drilling operations whether going into the hole with the drill pipe or whether removing same or whether in a stand-still condition. It further eliminates the necessity of any moving part required to accomplish any of such measurements from coming into physical contact with the drilling fluids themselves.

The basis for this invention is the general equation for pressure versus depth for any liquid: $P = 0.52\ D \times \rho$

where P = pressure in pounds per square inch;
D = depth in feet; and
ρ = density of liquid in lbs./gallon.

It will be apparent from the description of the drawings identified as Figures 1, 2 and 3, which follow below, that measurement of fluid depth (volumes) can be obtained independently of fluid weights (densities) and conversely that measurement of fluid weights can be obtained independently of fluid depths. (Please note that P_1, P_2, D_1, D_2 and D_3 are shown on Figure 1)

Applying the general equation set forth above, the pressure at pickup one (P_1) is:

$$P_1 = .052\ D_1 \times \rho$$

The pressure at pickup two (P_2) is:

$$P_2 = .052\ D_2 \times \rho$$

Then $P_2\text{-}P_1 = (.052 D_2 \times \rho) - .052\ D_1 \times \rho$

$$= .052\ \rho\ (D_2 - D_1)$$

But $D_2 - D_1 = D_3$

Then $P_2 - P_1 = .052\ \rho\ D_3$

or $\rho = \dfrac{P_2\text{-}P_1}{.052\ D_3}$

Since D_3 is a constant or fixed distance, the difference between P_2 and P_1, is directly proportional to the density (ρ).

Referring once more to the general equation:

$$P_2 = .052\, D_2\, \rho$$

$$\text{But } \rho = \frac{P_2 - P_1}{.052\, D_3}$$

$$\text{Then } P_2 = .052\, D_2 \left(\frac{P_2 - P_1}{.052\, D_3}\right)$$

$$= \frac{D_2}{D_3}(P_2 - P_1)$$

$$\text{Then } D_2 = \left(\frac{P_2}{P_2 - P_1}\right) D_3$$

$$\text{But } D_3 = \text{Constant}$$

Consequently, the depth D_2 is directly proportional to $\frac{P_2}{P_2 - P_1}$.

Referring now to Figure 1, pressure pick-ups P_1 and P_2 are connected to a differential pressure transmitter 1 (such as a "Taylor Instruments" differential pressure transmitter 303 T series A or B manufactured by Taylor Instrument Companies of Rochester, N.Y.), the output of which transmitter is represented in the above equation as $P_2 - P_1$ and is in fact directly proportional to the density of drilling fluid (mud) in units of pounds per gallon. Pressure pick-up P_2, is also connected to an absolute pressure transmitter 2. P_1 and P_2 are pressure pick-ups, and may comprise for example two strips of rubber between which air flows. The hydrostatic head of liquid pinches the two strips together causing a back pressure equivalent to the head of liquid. However, any suitable pick-up can be used. The output of the absolute pressure transmitter is made available as an input to a Sorteberg Bridge (type D) identified as 3D in the drawing, manufactured by Sorteberg Controls Corp. of Norwalk, Conn. (1973).

The output of the Sorteberg Bridge is transmitted through a biasing relay 3 (such as a Moore Products Biasing Relay manufactured by Moore Products under U.S. patent 2,501,957) for the purpose of adding the constant C, which is proportional to the mud depth below the pick-up P_2, with the resultant sum $\frac{P_2}{P_2 - P_1} + C$.

As further shown in Figure 1, the output of the differential pressure transmitter 1 is passed to a gauge 4 which displays mud densities (P_2-P_1) in units of pounds per gallon. This same output is also passed into the Sorteberg dividing bridge 3D in order that P_2 may be divided by P_2-P_1 with the resultant quotient added to constant C by the biasing relay 3, with the biasing relay output representing actual fluid (mud depth) depth D_4 which is supplied to a pit level indicating gauge 5 calibrated to show depth of mud in the pit in inches. Thus far, the apparatus and method illustrated in Figure 1 has furnished mud density automatically, without the necessity of physically weighing the mud, as is the present method of determining this measurement. At the same time the depth D_4 of the particular pit is made available to (referring now to Figure 2) an averaging relay 6, such as a Moore Products relay. The depths (D_4 of pits 1, 2 and 3) of all pits are transmitted to the averaging relay 6 the function of which will result in the average depth of all pits fed into it, and this $\left(\frac{D_4 \text{ (pits 1,2 and 3)}}{3}\right)$ average depth is fed into a Sorteberg Bridge, multiplying type, 3M where it will be multiplied by a pneumatic pressure representing barrels per foot, brls/ft., which is supplied into the system by pressure regulator 7. This is manually adjusted into the system at the regulator 7. The equipment in this system is preferably pneumatic, however, the system will function with electrical equipment as well. The resultant product of the multiplying bridge 3M is total barrels in all pits which is both recorded on a 24 hour recording gauge 8 as well as a continuous gauge 9.

A computing relay 10, such as a Moore Products Model 68-1, produces a differential in pressure representing change in total barrels of fluids (mud) and this is accomplished when a pressure supply is arbitrarily adjusted through a pressure regulator 11 so as to set the index at "zero" on a gain-loss gauge 12. This gain-loss gauge is a 0-15″ (inches) of water gauge with extreme sensitivity in readings and can be calibrated to show gains or losses from 0 to 20 barrels of fluids. A signal alarm can also be set to operate with the desired parameters as chosen by the well operator.

Figure 3 illustrates an entire fluid measuring system combining the functions of the system as shown and described in Figures 1 and 2. There is however added to this Figure 3 an additional system entirely devoted to and concerned with furnishing and displaying mud densities and volume 13 and 14 respectively, in the "Possum Belly". These are the volume and density of drilling fluids as they return from the well bore and many well operators consider this information important as noticeable changes therein may indicate an early warning of a dangerous or unwanted condition down-hole.

WHAT WE CLAIM IS:

1. A method of measuring volume and density of mud in a mud pit in a drilling fluid system comprising the steps of:

a) providing a first means for measuring pressure in a mud pit at a first position a fixed distance above the bottom of the pit;

b) providing a second means for measuring pressure in the mud pit at a second position a fixed distance above the first position;

c) connecting a first device to the first and second means to produce a signal proportional to the difference in pressures measured by the first and second means;

d) connecting a second device to the first means to produce a signal proportional to the pressure measured by the first means;

e) introducing the signals from the first and second devices as an input to a dividing bridge;

f) introducing the signal from the first device to a gauge displaying a reading of mud density;

g) communicating the output signal of the dividing bridge through a biasing relay to add a constant for the distance above the bottom of the mud pit of the first position at which pressure is measured by the first means, the output of the biasing relay representing the volume of the mud in the pit.

2. The method of claim 1 wherein a plurality of mud pits are employed each subjected to the steps of claim 1 further comprising:

a) communicating the biasing relay outputs for all additional pits to an averaging relay to provide an average depth value for all pits fed into it,

b) feeding the averaged depth value into a multiplying bridge to be multiplied by a value representing volume per unit depth and supplied into the system by a pressure regulator, the resultant product of said multiplying bridge being the total volume in all pits.

3. The method of claim 2 further comprising:

a) subjecting a pressure supply system to a pressure regulator in said supply system communicating with a computing relay to produce a differential in pressure representing the change in total volume of fluids when said pressure regulator is indexed at zero, and

b) communicating a gain-loss indicator gauge to the output of said computing relay and the output of said multiplying bridge to show gains or losses

4. The method of claim 1 comprising the step of furnishing and displaying mud densities and volume in the "Possum Belly" to provide a reading of the volume and density of drilling mud as they initially return from the well bore.

5. An apparatus for measuring volume and density of mud in a mud pit in a drilling fluid system comprising:

a) a first means for measuring pressure in a mud pit at a first position a fixed distance above the bottom of the pit;

b) a second means for measuring pressure in mud pit at a first position a fixed distance above the first position;

c) a first device connected to the first and second means for producing a signal proportional to the difference in pressures measured by the first and second means;

d) a second device connected to the first means for producing a signal proportional to the pressure measured by the first means;

e) a dividing bridge receiving the signals from the first and second devices;

f) a gauge receiving and displaying a reading proportional to the signal from the first device;

g) a biasing relay receiving the signal from the dividing bridge and adding a constant thereto; and

h) a gauge receiving and displaying a reading proportional to the signal from the biasing relay.

6. The apparatus of claim 5 wherein a plurality of pits are employed each equipped with the apparatus of claim 5 further comprising:

a) an averaging relay connected to said dividing bridge outputs for all additional pits to provide an average depth of all pits fed into it, and

b) means feeding the averaged depth into a multiplying bridge to be multiplied by a value representing volume per unit height and supplied into the system by a pressure regulator, the resultant product of said multiplying bridge being the total volume in all pits.

7. The apparatus of claim 6 further comprising:

a) a pressure supply system, a pressure regulator in said supply system connected to a computing relay to produce a differential in pressure representing change in total volume of fluids when said pressure regulator is indexed at zero, and

b) a gain-loss indicator gauge connected to the output of said computing relay to show gains or losses of volume of liquid.

8. The apparatus of claim 5 further comprising means for furnishing and displaying mud densities and volume in the "Possum Belly" to provide a reading of the volume and density of drilling fluids as they initially return from the well bore.

9. A method for measuring the volume and density of fluids in a drilling fluid system substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

10. Apparatus for measuring the volume and density of fluids in a drilling fluid system substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1980.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1583393 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

FIG. 1

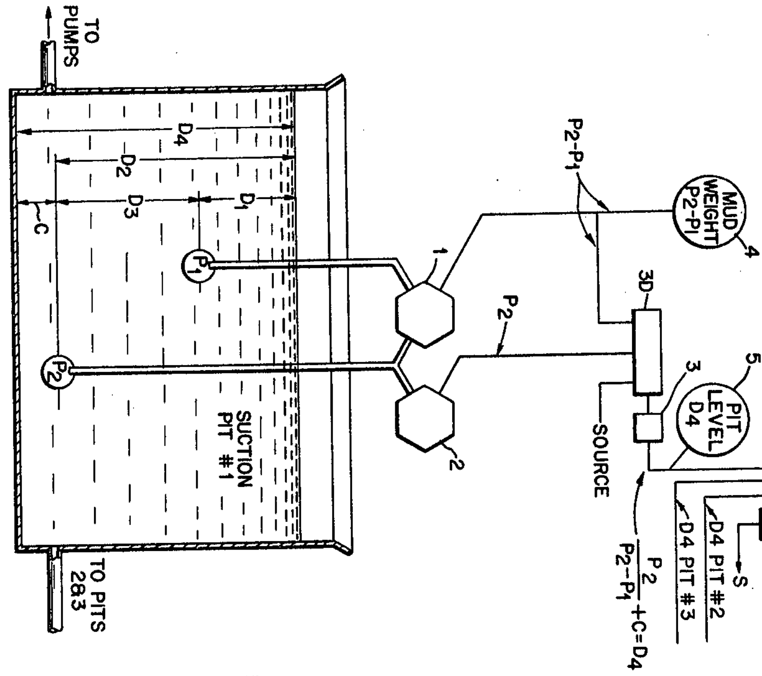
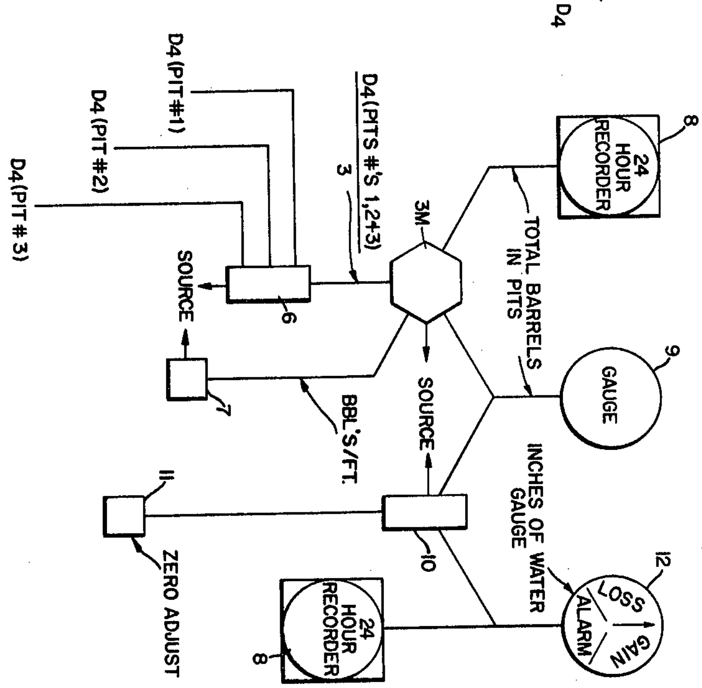


FIG. 2



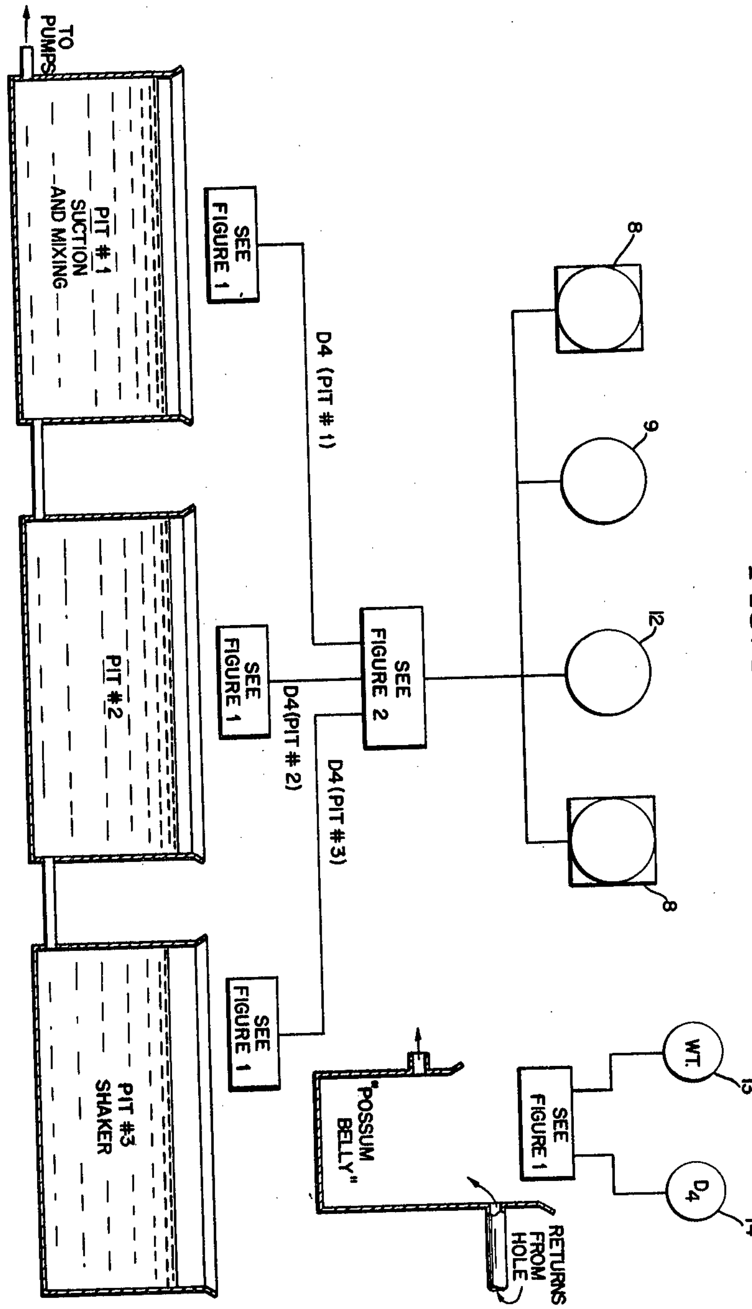

TO PUMPS
PIT # 1
SUCTION AND MIXING
SEE FIGURE 1
D4 (PIT # 1)
8
9
12
8
PIT # 2
SEE FIGURE 1
SEE FIGURE 2
D4(PIT # 2)
D4 (PIT #3)
PIT #3
SHAKER
SEE FIGURE 1
"POSSUM BELLY"
RETURNS FROM HOLE
SEE FIGURE 1
WT.
13
D4
14

FIG. 3