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[54] **APPARATUS FOR AUTOMATICALLY CONTROLLING THE KILLING OF OIL AND GAS WELLS**
9 Claims, 2 Drawing Figs.

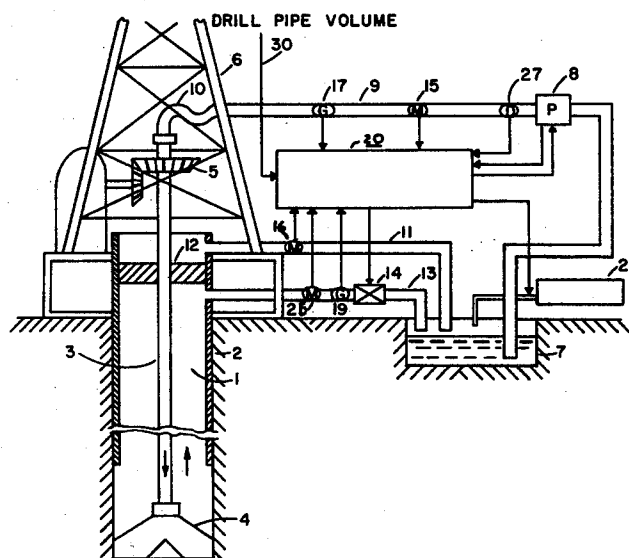
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E21b 21/00
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38, 40, 48, 65, 66, 218; 251/1; 166/53, 75, 86, 91;
73/151, 155, 434

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ABSTRACT: A pair of flow meters, one in the flow line and one in the stand pipe line, are connected into an alarm system, a sufficiently large differential indicating an impending blowout. The alarm system automatically lifts the kelly joint out of the rotary bushing, automatically slows the circulating mud pump and closes the blowout preventer. A computer utilizing sensed drill pipe pressure and the monitored mud weight and volume within the drill pipe controls an adjustable choke within a choke mud line located beneath the blowout preventer. The computer calculates the necessary mud weight to kill the well while circulating drilling fluid through the hole, and maintains a constant and correct pressure on the formation, while pumping out formation fluids that have invaded the well bore. The computer also causes barite to be automatically introduced into the mud tanks to raise drilling fluid to required weight.



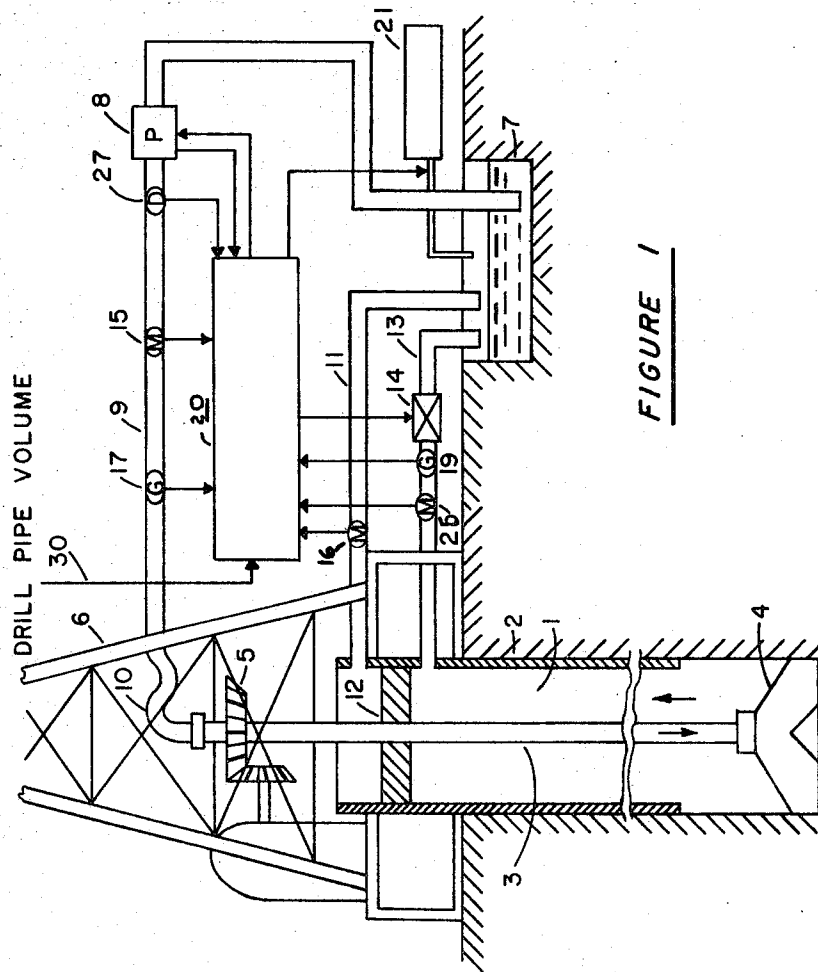


FIGURE 1

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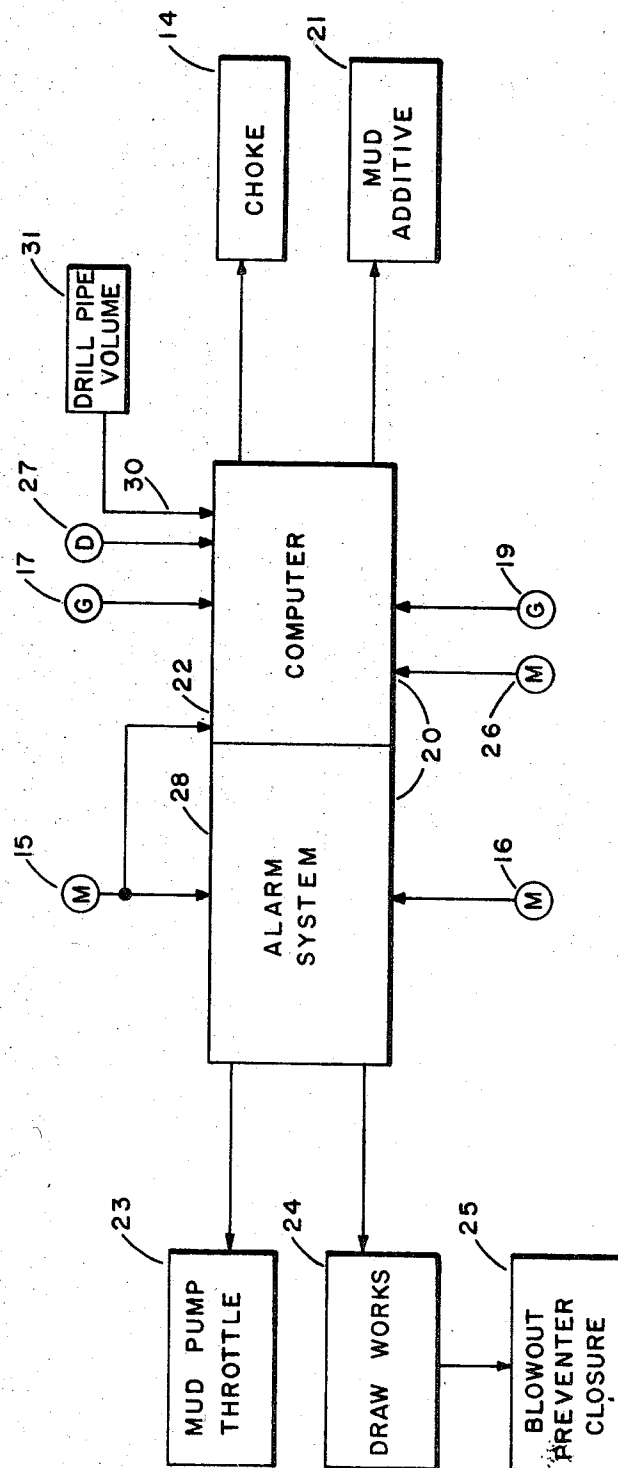


FIGURE 2

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APPARATUS FOR AUTOMATICALLY CONTROLLING THE KILLING OF OIL AND GAS WELLS

BACKGROUND OF THE INVENTION

This invention relates to methods and apparatus for killing oil and gas wells when the formation pressure at the bottom of the hole exceeds the hydrostatic pressure of the mud column within the hole and formation fluids flow into the well bore.

Such formation fluids, which may be gas, oil, water, or combination thereof, have low densities and the pressure difference which caused their flow, becomes even greater as these extraneous fluids rise in the well bore, displacing drilling mud out the top of the casing. When this occurs, a blowout is imminent unless the pressure difference which caused the formation fluid to flow into the well bore is controlled, as for example, by closing a blowout preventer such as is usually provided at the top of the well. Closing the blowout preventer in the well bore traps both the remaining mud and the foreign fluids and the formation will continue to produce until the pressure in the well bore becomes equal to or greater than formation pressure at corresponding depths, at which time fluid flow from the formation will cease. The driller is then faced with the problem of replacing the low density liquid column in the well bore with a column of sufficient density to contain the formation pressure. Furthermore, it is disadvantageous to simply pump in heavy mud because to do so can create an inordinately high pressure upon the formations and result in the fracturing of such formations.

A common practice within the prior art has been that of shutting in the well with the circulating pump stopped and then calculating the weight of the mud which should be pumped into the hole, based on shut-in drill pipe pressure. However, such a practice is disadvantageous in that the drill pipe often tends to stick whenever the well is shut in and the circulating pump stopped.

It is therefore a primary object of the invention to provide an automated control for killing oil and gas wells;

It is a further object of the invention to provide a method and apparatus for controlling oil and gas wells wherein there is no dependency upon stopping the circulating pump and shutting in the well.

The hereinbefore mentioned objects of this invention are, in general, accomplished by providing means for monitoring drill pipe pressure, mud volume and mud weight being pumped into the hole, and controlling an adjustable choke with such information. The system calculates the necessary mud weight to kill the well and controls the adjustable choke during the entire pumping time required to kill the well and to maintain constant and correct pressure on the formation. The system allows continued circulation of the drilling fluid while calculating shut-in drill pipe pressure and calculating mud weight required to kill the well.

Other objects, advantages, and features of the invention will be evident hereinafter in the more detailed description of the invention.

In the drawings, which illustrate the preferred embodiments and modes of operation of the invention, and in which like reference characters designate the same or similar parts throughout the several views:

FIG. 1 is a diagrammatical illustration of the mud circulating system according to the invention; and

FIG. 2 is a block diagram of the interaction of portions of the system according to FIG. 1.

Referring now to the accompanying drawings in detail, the well bore 1 having the usual casing 2 contains the drill stem 3 provided at its lower end with a bit 4, the stem 3 being turned by a rotary table 5 of the derrick 6. Drilling mud is pumped from a mud pit 7 by a positive displacement pump 8 through a mud delivery line 9 and flexible hose 10 into the drill stem 3, being discharged out of the bit 4 into the well bore 1 and returned from the top of the casing 2 by a mud flowline 11 to the mud pit 7. An openable and closable blowout preventer 12 of any suitable conventional type is provided at the upper end

of the casing 2, as shown. It should be appreciated that whereas the blowout preventer 12 is illustrated as being closed around the drill stem 3, the blowout preventer is maintained in an open position except during an impending kick so that the mud flow can occur in the flowline 11, all of which will be described in more detail hereinafter.

A secondary choke mud return line 13 is situated beneath the blowout preventer 12, having an adjustable choke 14 located therein for controlling the flow through the line 13 to equalize the flow of mud into and out of the hole 1 when blowout preventer 12 is closed.

A flow meter 15, a flow meter 16 and a flow meter 26 are located within the mudline 9, flow mudline 11 and chokeline 13, respectively.

A pressure gauge 17 and a pressure gauge 19 are located in the mudline 9 and the chokeline 13, respectively.

The various connections between the gauges, the meters, the pump, the choke, and the other parts of the system will be described in more detail with respect to FIG. 2, especially as how they relate to the alarm system and computer embodied within the block 20.

A barite dispenser 21, for example, a tank having discrete amounts of barite and means for dispensing a given number of those increments into the mud pit 7 to increase the mud weight, is also a part of the system and is controlled by the computer embodied within the block 20. Such a dispenser 21, although not illustrated, could for example have bins with solenoid driven gates which would allow the barite to be dispensed into the mud pit.

Referring now to both FIGS. 1 and 2, the block 20 is in actuality a combination of an alarm system 21 and a computer 22. The alarm system 21 is responsive to a predetermined flow differential as indicated by the flow meters 15 and 16. During normal drilling of the well, the flow meters 15 and 16 will provide approximately equal flow rates. When a kick is impending, a marked flow differential is created within the alarm system 21, for example, as by comparing electrical signals received from the flow meters 15 and 16 or by other means known in the art for indicating a difference between the two flow meters. Upon activation of the alarm system 21, a signal is imparted to the mud pump throttle 23, being an integral part of the mud pump 8. In the preferred embodiment, the pump 8 is automatically slowed to a predetermined rate to facilitate equalization of the mud flow into and out of the hole 1. The alarm system 21 also imparts a signal to the draw works 24, for example, a hydraulic or mechanical lifting device well known in the art. A signal from such a lifting device 24 then imparts a signal to the blowout preventer closure device 25 which likewise may be, for example, a conventional hydraulic or mechanical closing device. Thus it should be appreciated, that a predetermined flow differential existing between the flow meters 15 and 16 automatically sets the mud pump to a predetermined rate, automatically lifts the kelly joint, and automatically closes the blowout preventer.

It should be appreciated, however, that the operator of the drilling rig may wish to maintain certain degrees of control over the operation of the mud pump, the kelly joint, and the blowout preventer. This being the case, each of these three devices can be likewise operated manually. For example, the alarm system could in the alternative merely provide a red light and an audible indication, for example, a ringing bell. In such an alternative embodiment, the driller could manually throttle back on the circulating mud pump, he could then lift the kelly joint out of the rotary bushing, and manually close the blowout preventer.

The alarm system also imparts a signal to the computer 22 which then automatically controls the choke 14 to thereby restrict the flow of mud through the chokeline 13. It should be appreciated, however, that the computer 22 could likewise be activated by the driller pushing a button or throwing a switch upon the alarm system being activated, rather than being an automatic function of the alarm system.

The computer 22 receives inputs from flow meters 15 and 26, from densitometer 27 and from the pressure gauges 17 and 19 located in the mudline 9 and choke line 13.

In the operation of the computer, the shut-in drill pipe pressure is determined from the following relationship:

$$SIDPP = P_1 - cp; \text{ when } \Delta Q = 0 \quad (1)$$

∴ when flow meters

15 and 26 show no differential flow, where ΔQ = difference between flow into and out of hole, P_1 = drill pipe pressure and cp = predetermined slow rate circulating pressure, being the sum of pressure losses of the entire system at the reduced circulating rate prior to the kick.

The mud weight required to kill a kick is computed from the following relationship:

$$W_{tr} = W_{to} + \frac{P_1 - cp}{0.052D} + K \quad (2)$$

where w_{tr} = required mud weight to kill the kick, W_{to} = mud weight at the time of the kick as measured by densitometer 27 in mudline 9, P_1 = drill pipe pressure at the time when $\Delta Q = 0$, cp = predetermined slow rate circulating pressure (the friction losses in the system), 0.052 = dimensional constant D = length of drill pipe and K = safety margin.

As the mud weight is raised to the necessary W_{tr} , it is necessary to calculate the circulating pressure and to control this pressure as the mud weight varies. The computed pressure can be found from the following relationship:

$$CP_{(n-1) \rightarrow n} = cp \left(\frac{W_{ti}}{W_{to}} \right) + P_1 - cp - \left[0.052D (W_{ti} - W_{to}) \frac{1}{x} \right] - \sum_{i=1}^{i=x-1} A_i \quad (3)$$

where:

$$A_{(n-1) \rightarrow n} = \left[0.052D (W_{ti} - W_{to}) \frac{1}{x} \right],$$

$CP_{(n-1) \rightarrow n}$ = Calculated

circulating pressure, n = the n th iterative evaluation of CP , n ** 1, cp = predetermined slow rate circulating pressure, i = the i th segment in the drill pipe (varies from 1 to $x-1$), W_{ti} = weight of mud entering the drill pipe, W_{to} = weight of mud at

time of kick, $A = \left[0.052D (W_{ti} - W_{to}) \frac{1}{x} \right]$

P_1 = drill pipe pressure at time when $\Delta Q = 0$, 0.052 = dimensional constant, D = length of drill pipe, X = number of increments drill pipe volume is divided into for summation of

weights, $\frac{1}{X}$ = percentage of drill pipe volume for each increment expressed as a decimal,

$$0.052 (W_{ti} - W_{to}) \frac{1}{X} = \text{static head pressure}$$

associated with top $\frac{100}{X}\%$ of mud in drill pipe,

and

$$\sum_{i=1}^{i=x-1} A_i = \text{static head pressure associated with bottom} \left(100 - \frac{100}{x} \right) \% \text{ of mud in the drill pipe.}$$

It should be appreciated that as each incremental volume of mud is pumped into the drill pipe, an equal increment goes out of the bottom. The static head pressure will thus drop off the head caused by the bottom increment and replace it with the top increment.

The circuitry within the computer 22 determines the pressure CP , compares it to the stand pipe pressure from pressure gauge 17, then adjusts the choke 14 and subsequently the stand pipe pressure to the computed value.

The computation of CP and choke adjustment continues until a reset button (not illustrated) is activated. When the kick is killed, W_{tr} will have circulated all the way around and CP will equal cp plus the increase in system loss caused by the mud weight increase.

It should be appreciated that either an analogue or digital computer will suffice for operation of the system described herein.

The barite dispenser 21, being automatically controlled by the W_{tr} computations, puts out the proper amount of barite into the mud pit 7. As an alternative, the mud engineer could manually adjust the mud weight based upon the output of the computer 22.

Thus there has been described and illustrated a completely automated preferred embodiment of a method and apparatus for killing an oil or gas well wherein there is an impending kick. Various modifications of the system will occur to those skilled in the art without departing from the spirit of the invention herein described. Accordingly, it is not desired to limit the invention to this disclosure and various modifications and equivalents may be resorted to, falling within the spirit and scope of the invention as claimed.

I claim:

1. In a well mud circulating system including a drill stem discharging mud into a well bore, a blowout preventer device located near the upper end of said well bore, a mud return line extending from the well bore above said blowout preventer to a mud pit and a mud delivery line extending from the mud pit to the drill stem, apparatus for maintaining balanced mud circulation in said system to prevent blowout of the well by pressure of extraneous fluids in the well bore, said apparatus comprising:

- a. a secondary mud return line located beneath the blowout preventer device, said secondary line having a flow meter and an adjustable choke therein;
- b. a flow meter in said delivery line;
- c. means for monitoring the weight of mud being pumped into the hole;
- d. means for monitoring the mud pressure in both the mud delivery line and in said secondary return line; and
- e. computer means connected to and responsive to said flow meters, said means for monitoring the weight of mud, said adjustable choke, and said pressure monitoring means for maintaining balanced mud circulation by adjustment of said choke to vary flow through said secondary mud return line.

2. The system according to claim 1 comprising in addition thereto, means for automatically calculating the mud weight required to kill the kick.

3. The system according to claim 1, comprising in addition thereto, means to automatically increase the weight of the circulating mud, responsive to said computer means.

4. In a well mud circulating system including a drill stem discharging mud into a well bore, a blowout preventer device located near the upper end of said well bore and a mud delivery line extending from a mud pit to the drill stem, apparatus to prevent blowout of the well by pressure of extraneous fluids in the well bore, said apparatus comprising:

- a. a mud return line extending from the well bore to the mud pit, said return line being located beneath the blowout of the well by pressure of extraneous fluids in the well bore, said apparatus comprising: preventer and having an adjustable choke therein;
- b. means for monitoring the flow of the circulating mud including a first flow meter in said mud delivery line and a second flow meter in said return line;
- c. means for monitoring the weight of the mud being pumped into the hole;
- d. means for monitoring the mud pressure in both the mud delivery line and in said return line;
- e. computer means connected to said first flow meter, second flow meter, means for monitoring the weight of mud, adjustable choke, and pressure monitoring means to

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generate an alarm signal when the flow out of the secondary flowline exceeds the flow in said delivery line by a predetermined amount and to prevent blowout by adjustment of said choke thereby varying flow through said return line; and

f. alarm means responsive to said alarm signal.

5. The system according to claim 4 comprising in addition thereto, means for automatically calculating the mud weight required to kill the kick.

6. The system according to claim 4, comprising in addition thereto, means to automatically increase the weight of the circulating mud, responsive to said computer means.

7. In a well mud circulating system including a drill stem discharging mud into a well bore, a blowout preventer device, located near the upper end of said well bore, a mud return line extending from the well bore above said blowout preventer device to a mud pit and a mud delivery line extending from the mud pit to the drill stem, apparatus for maintaining balanced mud circulating in said system to prevent blowout of the well by pressure of extraneous fluids in the well bore, said apparatus comprising:

- a. a first mud flow meter in said mud delivery line;
- b. a second mud flow meter in said mud return line;
- c. means to compare the flow rates in said first and second meters;

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d. means to close said blowout preventer device, responsive to a predetermined difference between said flow rates;

e. a secondary mud return line located beneath the blowout preventer device, said secondary line having a flow meter and an adjustable choke therein;

f. means for monitoring the volume of the circulating mud;

g. means for monitoring the weight of the mud being pumped into the hole;

h. means for monitoring the mud pressure in both the mud delivery line and in said secondary return line; and

i. computer means utilizing said volume monitoring means and said pressure monitoring means by comparing the volumes and pressures monitored by said volume monitoring means and said pressure monitoring means, to control said adjustable choke so as to vary flow in said secondary return line, thereby equalizing the flow of mud into and out of said well.

8. The system according to claim 7 comprising in addition thereto, means for automatically calculating the mud weight required to kill the kick.

9. The system according to claim 7 comprising in addition thereto, means to automatically increase the weight of the circulating mud, responsive to said computer means.

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