United States Patent

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[54] **METHOD AND APPARATUS FOR MONITORING POTENTIAL OR LOST CIRCULATION IN AN EARTH BOREHOLE**
8 Claims, 1 Drawing Fig.

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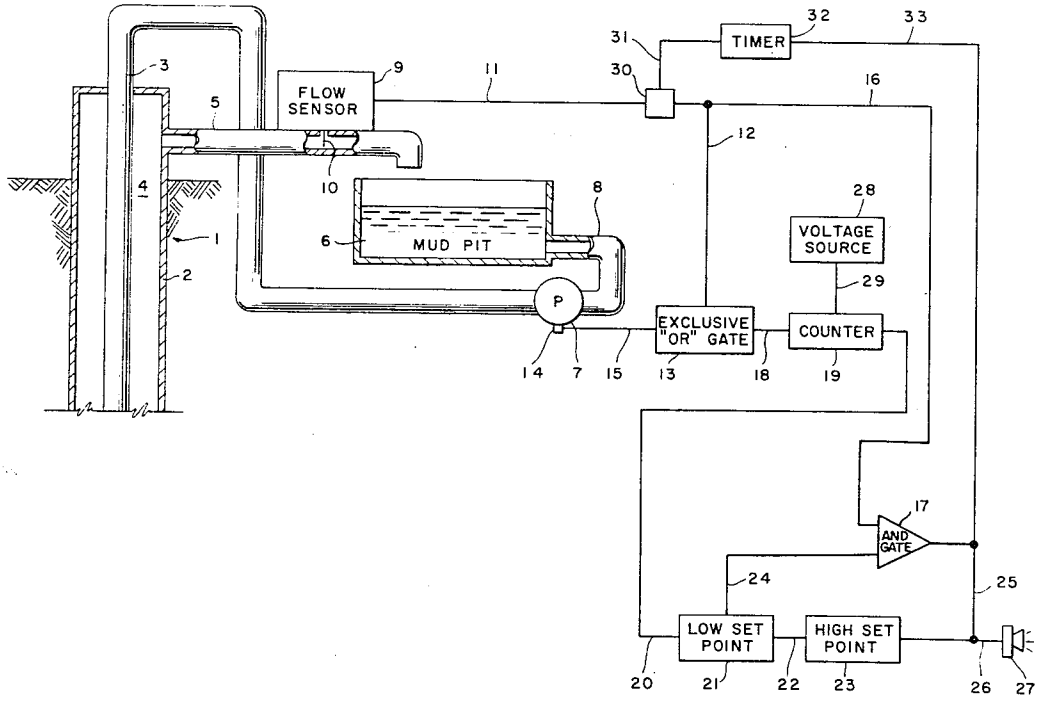
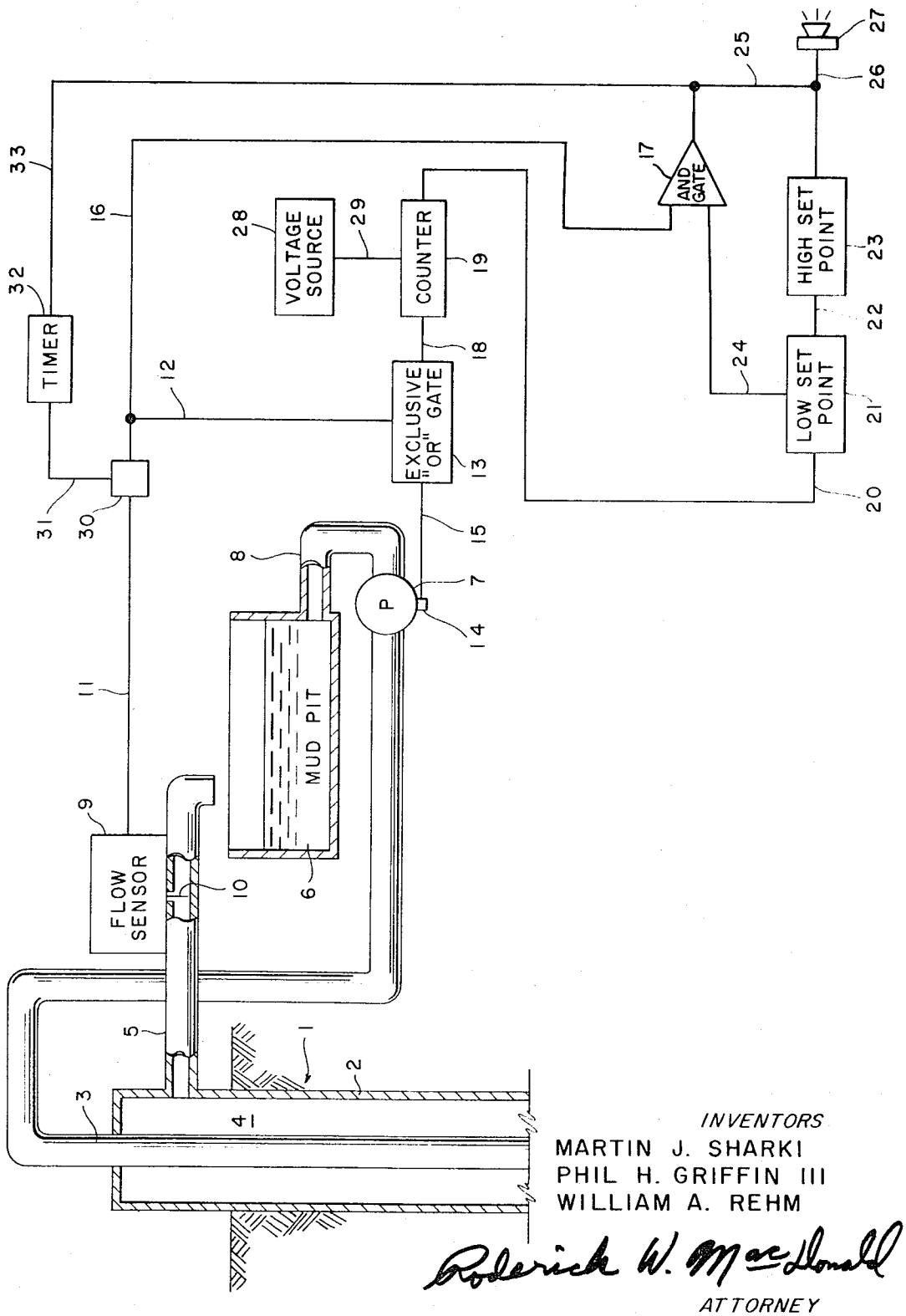
ABSTRACT: Method and apparatus for monitoring potential blowouts or lost circulation in a well by employing sensing devices on the drilling fluid pump and the well bore return pipe for the drilling fluid. Means are provided for monitoring the drilling fluid pumped into the well bore and for sounding a warning if a certain amount of drilling fluid flows out of the well bore before a minimum amount of drilling fluid is pumped into the well bore. Means are also provided for sounding the warning if no drilling fluid flows out of the well bore and the certain maximum amount of drilling fluid has been pumped into the well bore.





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METHOD AND APPARATUS FOR MONITORING POTENTIAL OR LOST CIRCULATION IN AN EARTH BOREHOLE

BACKGROUND OF THE INVENTION

In drilling a well for oil, gas, water, and the like the drilling bit is supported in the well bore by tubing. The tubing is hollow pipe composed of a plurality of individual lengths (stands) of pipe connected together. The tubing carries drilling fluid in its interior down to and through the drilling bit. The drilling fluid at the bottom of the well bore passes upwardly in the annulus between the exterior surface of the tubing and the interior surface of the well bore to the surface of the earth and then through a return pipe to storage pits on the surface of the earth commonly referred to as mud pits. The weight of the drilling fluid in the well bore helps maintain a high pressure at the bottom of the bore thereby preventing the intrusion into the bore of undesired lighter materials such as gas, water, and the like. This is desirable because the intrusion of these materials forces drilling fluid from the well bore through the return pipe and a dangerous and expensive blowout can occur because of the reduced pressure in the bore.

Also, when drilling a well a particularly porous geologic formation can be encountered into which is lost substantial amounts of drilling fluid. This is a lost circulation situation which can be expensive and harmful to the overall drilling operation.

Oftentimes during the drilling operation the drilling bit becomes worn and has to be replaced. This calls for removing all of the tubing from the well bore. When tubing is removed from the well bore a very great risk of a blowout is run since the drilling fluid liquid head in the well bore is shortened by the withdrawal of the tubing and the volume consumed in the well bore by that tubing. Therefore, the pressure at the bottom of the well bore is substantially reduced thereby causing the danger of a blowout.

Normally the process followed when removing tubing from the well bore is to first calculate by conventional procedures well known in the art the volume of drilling fluid needed to fill the volume vacated in the well bore by each stand of tubing. One or more stands of tubing are then withdrawn from the well bore and the withdrawal of tubing stopped. The well bore is then filled with the volume of the drilling fluid calculated to be necessary to fill the volume vacated by the stands of tubing withdrawn. Then one or more additional stands of tubing are withdrawn and the process repeated until all the tubing is removed from the well bore.

It is during this process that it is extremely desirable to have as much forewarning as possible against a potential blowout. It is also desirably to have a warning of a lost circulation problem.

It is also helpful to have similar warnings when the tubing carrying the new drilling bit is replaced in the well bore.

SUMMARY OF THE INVENTION

According to this invention, there is provided apparatus for warning against potential blowouts or lost circulation problems by employing warning means which take signals from the pump which pumps drilling fluid from the mud pits into the tubing and from flow sensing means on the outlet pipe which carries drilling fluid from the annulus between the exterior of the tubing and the interior of the well bore to the mud pits.

The method of this invention comprises in its improved aspect the determination of minimum and maximum tolerable amounts of drilling fluid to be pumped into the well bore to compensate for the withdrawn tubing, measuring the amount of drilling fluid actually pumped into the well bore, and sounding a warning when certain situations as hereinafter defined are sensed bases upon pumping of the drilling fluid into the tubing and/or flow of drilling fluid from the well bore to the mud pits.

This invention also includes apparatus for use when tubing is being reinserted into the well bore which employs timing means which receives a signal from a flow sensor on the outlet pipe of the well bore and which is also operatively connected to a warning means. The corresponding method for this aspect of the apparatus of this invention comprises, in its improvement, the determination of the amount of drilling fluid to be displaced from the well bore by the amount of tubing to be reinserted in the well bore, measuring the amount of drilling fluid actually displaced from the well bore, and sounding a warning if more than the determined amount of drilling fluid is actually displaced from the well bore.

Accordingly, it is an object of this invention to provide a new and improved method and apparatus for monitoring the drilling of a well. It is another object to provide a new and improved method and apparatus for monitoring a well for a potential blowout or lost circulation problem while removing tubing from the well bore. It is another object to provide a new and improved method and apparatus for monitoring a potential blowout or lost circulation problem when tubing is being inserted into the well bore.

Other aspects, objects, and advantages of the invention will be apparent to those skilled in the art from the disclosure and the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

The drawing shows a system embodying this invention.

More specifically, the drawing shows a well bore 1 lines with conventional casing 2 and having tubing 3 inserted therein thereby defining annulus 4 between tubing 3 and casing 2. Annulus 4 is operatively connected with the interior of outlet pipe 5.

Pipe 5 conducts returning drilling fluid from annulus 4 to drilling fluid storage pit 6.

As additional drilling fluid is needed, it is removed from pit 6 by pump 7 through line 8 and into tubing 3 to travel downwardly through tubing 3 to the bottom of the tubing and the drilling bit at the bottom of the borehole (not shown).

Pump 7 is a conventional piston-type reciprocating pump which pumps a known volume of liquid each time the piston passes through one reciprocation cycle, i.e., movement forward to the full extended position and then movement backward to the original starting position. This known volume is provided by the manufacturer of the pump so that the number of reciprocation cycles (pump strokes) of the pump required to deliver a desired volume of drilling fluid can be readily ascertained in a conventional manner well known in the art.

Pump 7 carries a sensing device such as a microswitch which will register each reciprocation cycle of the pump piston. A signal representative of each reciprocation cycle is passed by electrical line 15 to a conventional electronic device well known in the art as an "exclusive OR " gate the function of which is described hereinafter.

Gate 13 can be electromechanical, e.g., through the use of conventional relays, or can employ solid-state circuits whichever is desired by those skilled in the art.

Gate 13 is operably connected by way of electrical line 18 to a conventional counter 19 which is used for totaling the number of reciprocation cycles registered by switch 14. Suitably counters are commercially available and well known in the art. For example, a suitably counter is the Unipulser, type 49000–405, manufactured by Durant Company of Milwaukee, Wisconsin.

Counter 19 is operated by its own voltage source 28 which is connected to counter 19 by way of electrical line 29. A signal from counter 19 actually comes from voltage source 28 and not from gate 13 and is passed by electrical line 20 to low set point device 21.

The low set point device is a commercially available and well known device. A suitably device is the Uniset Switch, type 40 500–400, manufactured by Durant Company of Milwaukee, Wisconsin.

Low set point device 21 is operably connected by way of electrical line 22 to a high set point device 23 which can be the same device as device 21 except that it is used to register a maximum total of reciprocation cycles of pump 7 rather than a minimum total of reciprocation cycles of pump 7 which is the function of low set point device 21.

Device 21 is also operably connected by way of electrical line 24 to a conventional AND gate the function of which will also be described hereinafter. Gate 17, like gate 13, is a conventional piece of apparatus well known in the art and can employ either electromechanical relays or solid-state circuits as desired.

High set point device 23 is operably connected by way of electrical line 26 to a warning device 27. Gate 17 is also operably connected by way of electrical line 25 and line 26 to warning device 27.

Warning device 27 can be any device desired such as a horn, whistle, light, and the like.

A conventional flow sensor switch 9 is operably mounted on pipe 5 with a paddle means 10 extending down into the interior of pipe 5 to sense the presence of flow, if any, of the drilling fluid in pipe 5. For example, if the flow starts, paddle 11 is moved toward the outlet end nearest pit 6 whereas if the flow stops, paddle 10, being spring biased in that direction, moves towards the inlet end of pipe 5 in casing 2.

The electrical signal output of flow switch 9 is carried by way of electrical lines 11 and 16 to gate 17.

Between lines 11 and 16 there is operably connected a conventional switch means 30 which can divert the signal in line 11 from line 16 to line 31 and timer 32. Timer 32 can be any conventional apparatus commercially available and known in the art such as the Time Delay Relay, type TDO–62C30–115 A, produced by Guardian of Chicago, Illinois.

Timer 32 is operatively connected by way of electrical lines 33, 25, and 26 to warning device 27.

Gate 13 receives intermittent signals from switch 14, each signal being representative of one reciprocation cycle of pump 7 and therefore also being representative of the pumping of a finite and know volume of drilling fluid into tubing 3 and into the well bore. Gate 13 is an "exclusive OR " gate because it passes the intermittent signals from switch 14 to counter 19 so long as it does not receive a signal from flow sensor 9 by way of electrical lines 11 and 12. If a signal is received by gate 13 from flow sensor 9 it will stop passing signals from switch 14 on to counter 19 and thereby stop the operation of counter 19 in its function of totaling the number of reciprocation cycles of pump 7. Thus, gate 13 will pass signals received from switch 14 as long as no signal is also received from flow sensor 9 and when a signal is received from sensor 9 the operation of the system is stopped by gate 13.

The current from source 28 passes through counter 19 and through device 21 to either gate 17 or device 23. When the total reciprocation cycles registered by counter 19 is less than the low set point on device 21, the signal from source 28 is passed to gate 17. When the total reciprocation cycles registered by counter 19 exceeds the low set point on device 21, the signal from source 28 is not passed to gate 17 by rather is passed to device 23 instead. Device 23 does not pass the signal on to warning device 27 unless and until the total number of reciprocation cycles registered by counter 19 exceeds the high set point on device 23.

Gate 17, when receiving a signal from device 21 will not pass that signal on to warning device 27 unless and until a signal is received from flow sensor 9 by way of lines 11 and 16. Thus, this gate is an AND gate because it will not pass a signal on to warning device 27 until it receives signals from both device 21 and flow switch 9.

If the total number of reciprocation cycles registered by counter 19 is less than the low set point on device 21, the signal from source 28 is passed to gate 17 and not to device 23. In this situation if a signal is received from flow switch 9, gate 17 will pass the signal on to warning device 27. If the total number of reciprocation cycles registered by counter 19 exceeds the low set point on device 21 the signal from source 28 is not passed to gate 17 but rather is passed to device 23 which does not pass the signal on to warning device 27 unless and until the total number reciprocation cycles registered by counter 19 exceeds the high set point on device 23.

Thus, when the total number of reciprocation cycles registered on counter 19 (which is representative of the total number of pumping strokes of pump 7) is less than the lower set point on device 21 warning device 27 is not actuated unless a signal is also received from flow sensor 9 in which case a warning device is actuated.

When the total number of reciprocation cycles on counter 19 is greater than the low set point on device 21 but less than the high set point on device 23, warning device 27 is not actuated.

When the total number of reciprocation cycles on counter 19 is greater than the high set point on device 23, warning device 27 is actuated.

In operation in the situation wherein tubing 3 is being withdrawn from the well bore and the number of stands of tubing that are to be withdrawn at each step is known and the volume of drilling fluid needed to fill the volume of the well bore vacated by the withdrawn tubing has been calculated together with the number of reciprocation cycles of pump 7 needed to supply this calculated volume of drilling fluid, the number of stands of tubing upon which the calculations were based are withdrawn from the well bore and the withdrawal of tubing 3 is stopped.

The low set point on device 21 and the high set point on device 23 are set to bracket the number of reciprocation cycles calculated to be necessary for pump 7 to deliver to the well bore the volume of drilling fluid calculated to be necessary to fill the volume vacated by the withdrawn stands of tubing. It is preferable that the calculated number of reciprocation cycles for pump 7 be employed as the low set point for device 21 so that a warning is given as soon as the calculated number of reciprocation cycles is exceeded thereby giving the very earliest advance warning. The high set point for device 23 can be set at any number of reciprocation cycles higher than the calculated number of reciprocation cycles, e.g., 10 percent higher. This maximum set point is an arbitrary set point and can be less than 10 percent or more than 10 percent higher than the calculated number of reciprocation cycles. Pump 7 is started to pump drilling fluid into tubing 3 to fill the well bore.

If during during the withdrawal of tubing from the borehole, there is an impending blowout, alien fluid will intrude into the borehole and this intrusion will cause the total number of reciprocation cycles of pump 7 to fill the borehole with less than the calculated number. In this situation, the total number of reciprocation cycles registered on counter 19 will be less than the low set point on device 21 and the signal from source 28 will be applied to gate 17. Also in this situation liquid will flow from annulus 4 through pipe 5 before it would ordinarily since annulus 4 is prematurely full because of the intruding alien fluid. The annulus is thus filled while pump 7 is pumping. Thus, paddle 10 will be deflected toward the outlet end of pipe 5 adjacent pit 6 beyond its set point and will cause a signal to be passed from flow switch 9 through lines 11 and 16 to gate 17. When a signal is received by gate 17 from flow switch 9 and at the same time receives a signal from source 28, the gate will open and pass a signal to device 27 thereby sounding a warning of an impending blowout.

If there is no impending blowout while pump 7 is being operated to fill the well bore, the total number of reciprocation cycles registered by counter 19 will reach or exceed the low set point on device 21 thereby causing the signal from source 28 to be switched from gate 17 to high set device 23. During this situation if a signal is received from flow sensor 9 caused by the flow of liquid through pipe 5 and deflection of paddle 10 past its set point toward the outlet end of pipe 5 adjacent pit 6, a signal is passed to gate 17 but since a signal from source 28 is not also imposed on gate 17 by way of line 24, no signal is passed on to warning device 27. Instead, the signal

from flow sensor 9 passes to gate 13 by way of line 12. When gate 13 receives the signal from flow sensor 9 it will stop passing signals from switch 14 on to counter 19 thereby stopping counter 19 and the operation of the system. This same stoppage of counter 19 by impressing a signal from flow switch 9 on gate 13 by way of line 12 occurs when a signal is imposed on gate 17 by way of line 24 but in this case, even though counter 19 is stopped by gate 13, the signal from source 28 is passed through gate 17 to actuate warning device 27. However, in the present situation wherein the total number of reciprocation cycles on counter 19 exceeds the low set point of device 21 so that the signal of source 28 is not imposed on gate 17 but rather is imposed on device 23, the reception of a signal from flow switch 9 at gate 13 merely stops counter 19 and therefore operation of the system without actuating warning device 27.

If the total number of reciprocation cycles on counter 19 exceeds the low set point on device 21 and then goes on to exceed the high set point of device 23, the signal from source 28 is then passed to warning device 27 to actuated same because this indicates an unduly large amount of drilling fluid has been pumped into tubing 3 without filling the annulus and causing a consequent flow of liquid in pipe 5. If a flow of liquid had been achieved in pipe 5 before reaching the high set point of device 23, flow switch 9 would have passed a signal to gate 13 thereby stopping the operation of counter 19 and trapping the signal from source 28 in device 23. However, when the total number of reciprocation cycles on counter 19 exceeds the high set point on device 23, warning device 27 is actuated and in this instance warns of a lost circulation problem since more than the calculated amount of drilling fluid has been pumped into tubing 3 without liquid flow in pipe 5.

In operation wherein tubing 3 is being reinserted into the well bore, switch 30 is switched so as to pass signals from flow switch 9 in line 11 to line 31 instead of to lines 12 and 16. It is determined empirically by actual experience how long drilling fluid should be displaced from the annulus and should flow through pipe 5 when a single stand of tubing is inserted into the well bore. In this manner, the time period of drilling fluid flow in pipe 5 is known and timer 32 is set to run for this time period. Flow switch 9 is set to indicate liquid flow in pipe 5 toward the outlet end of pipe 5 adjacent pit 6 in a short order so that timer 32 can be started running as soon as there is flow in pipe 5. It should be noted that timer 32 runs only while flow sensor 9 indicates liquid flow and if liquid flow in pipe 5 stops, thereby allowing paddle 10 to move to its normal position, timer 32 also stops running and is reset to zero time.

Thus, when flow sensor 9 first indicates liquid flow in pipe 5 timer 32 starts running. If the drilling fluid flow in pipe 5 runs longer than the time period set for timer 32, timer 32 times out and passes the signal from flow sensor 9 through lines 33, 25, and 26 to warning device 27 thereby sounding a warning. This warning indicates that there is intrusion of alien fluid in the well bore and that this intrusion is pushing the drilling fluid out of the annulus in amounts greater than those amounts normally displaced by the tubing being inserted into the well bore.

If the drilling fluid stops before timer 32 times out no warning is sounded because flow sensor 9 stops indicating liquid flow in pipe 5 before timer 32 times out.

Thus, impending blowouts are warned of when tubing 3 is being reinserted into the well bore as well as when that tubing is being withdrawn from the well bore.

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

1. In apparatus for monitoring potential blowouts and lost circulation in a well wherein a conduit means returns drilling fluid from the well bore and a reciprocating pump means transfer drilling fluid to said well bore, the improvement comprising in combination liquid-flow-sensing means operatively connected to said conduit means, means for registering each reciprocation cycle of said pump means, counter means for totaling the number of reciprocation cycles registered by said registration means, means for setting minimum and maximum totals of reciprocation cycles, warning means, and gate means for actuating said warning means when one of the following occurs:
   1. the total number of reciprocation cycles is less than the set minimum and liquid flow is sensed by said liquid-flow-sensing means, and
   2. the total number of reciprocation cycles exceeds the set maximum and no liquid flow is previously sensed by said liquid-flow-sensing means.

2. The apparatus according to claim 1 wherein timer means is operatively connected between said liquid-flow-sensing means and said warning means, and switch means for electrically isolating said timer from the apparatus of claim 1.

3. The apparatus according to claim 2 wherein said timer means starts running when the signal is received from said liquid-flow-sensing means and continues to run as long as said signal is received but stops when said signal is no longer received so that the signal is not passed on to said warning means if said signal stops before said timer times out.

4. The apparatus according to claim 1 wherein said gate means comprises an AND gate operatively connected between said means for setting said minimum reciprocation cycles total and said warning means, and an "exclusive OR" gate operatively connected between said means for registering each reciprocation cycle and said counter means so that said AND gate receives a signal from said counter means so long as the total reciprocation cycles counted by said counter means is less than the set minimum but does not pass said signal or unless and until a signal is also received from said liquid flow sensing means, and said "exclusive OR" gate receives signal pulses from said means for registering each reciprocation cycle and passes same on to said counter means unless and until a signal is received from said liquid-flow-sensing means.

5. The apparatus according to claim 3 wherein said means for registering each reciprocation cycle is a microswitch carried by said pump means.

6. A method for monitoring potential blowouts and lost circulation in a well wherein drilling fluid is pumped into the well bore, the improvement comprising determining minimum and maximum tolerably amounts of drilling fluid to be pumped into said well bore, measuring the amount of drilling fluid actually pumped into said well bore, sounding a warning if drilling fluid flows out of said well bore before said set minimum amount of drilling fluid is pumped into said well bore, and sounding a warning if no drilling fluid flows out of said well bore and said set maximum amount of drilling fluid has been pumped into said well bore.

7. The method according to claim 6 wherein said method is employed when removing tubing from the well bore.

8. The method according to claim 7 wherein when tubing is being inserted in said well bore, determining the amount of drilling fluid to be displaced out of the well bore by the amount of tubing to be inserted, measuring the amount of drilling fluid actually displaced, and sounding a warning if more than the determined amount of drilling fluid is actually displaced from said well bore.