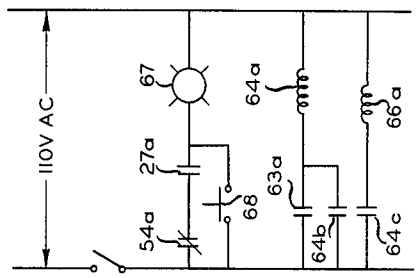
FIP8011 OR 3,198,250 SEARCH ROOM

Aug. 3, 1965 R. S. HOCH ETAL 3,198,250

WELL OPERATION

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FIG. 2



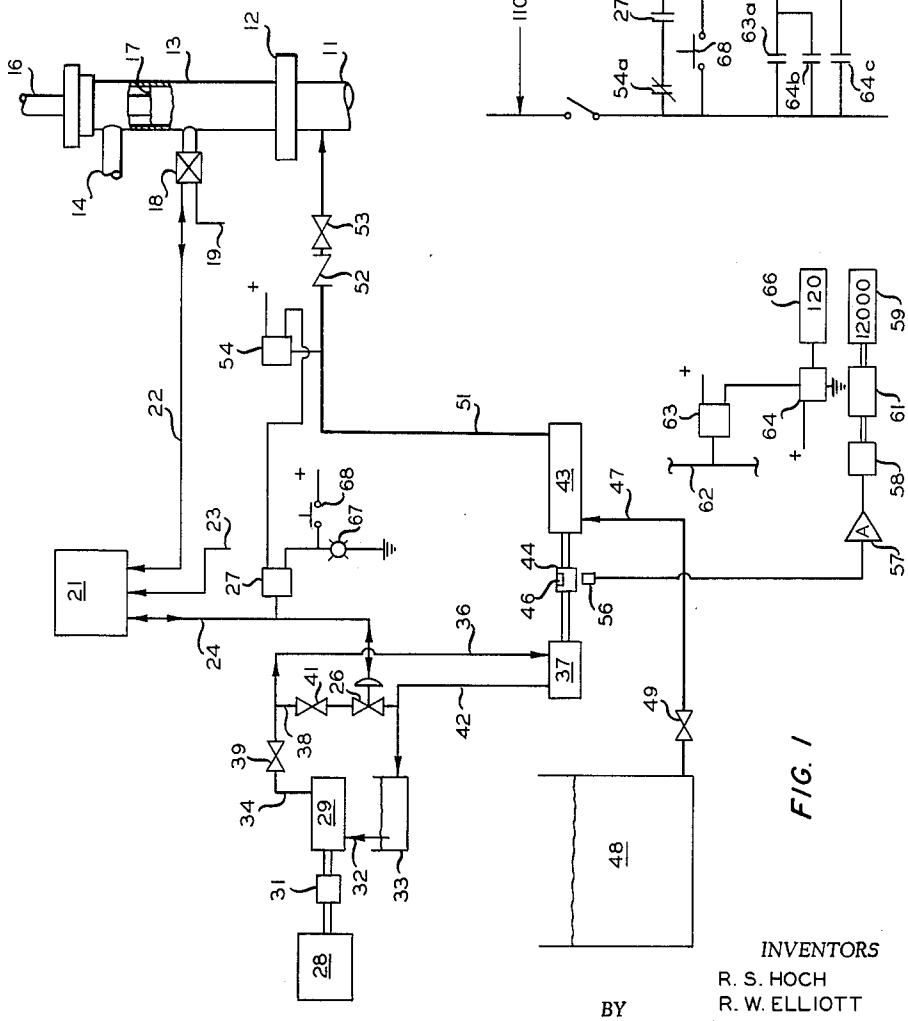


FIG. 1

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WELL OPERATION

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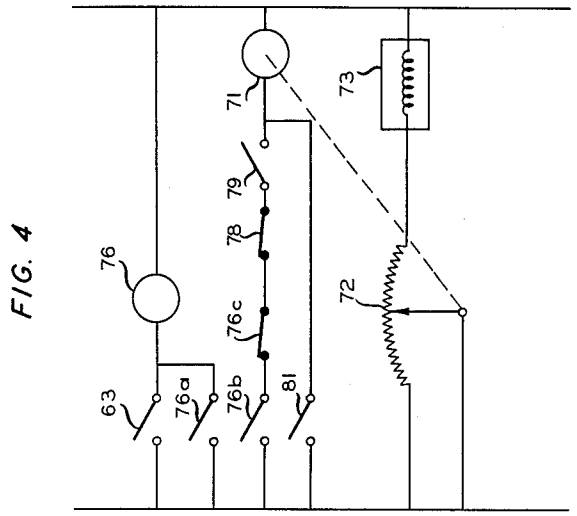


FIG. 4

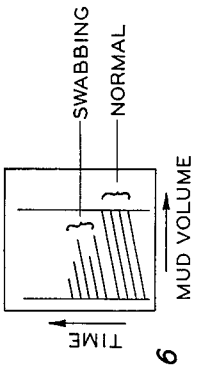


FIG. 6

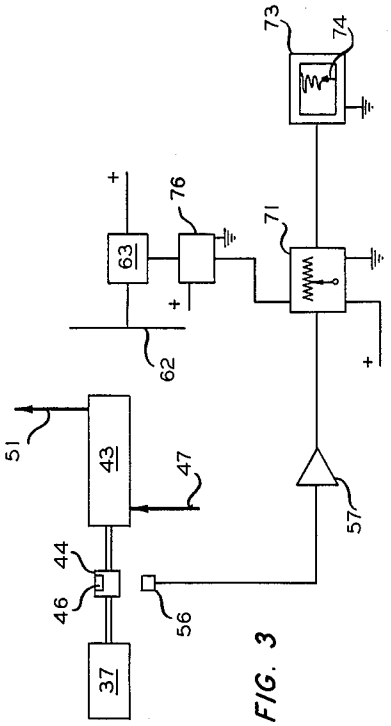


FIG. 3

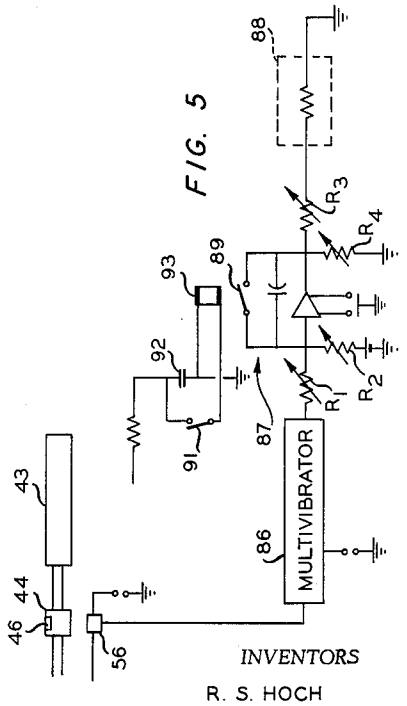


FIG. 5

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United States Patent Office 3,198,250 Patented Aug. 3, 1965

3,198,250

WELL OPERATION

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Filed Dec. 31, 1962, Ser. No. 248,388
9 Claims. (Cl. 166—4)

This invention relates to well operation. In one aspect the invention relates to the prevention of blowout while removing pipe from a drilling well. In another aspect the invention relates to apparatus for automatically maintaining the level of mud in a well and for recording the amount of mud added for comparison with the pipe removed. In another aspect the invention relates to a method for detecting an incipient blowout. In another aspect the invention relates to a method for preventing blowout.

In drilling oil and gas wells, and in reworking such wells, one of the functions performed by the drilling fluid is that of providing sufficient pressure in the vicinity of underground high-pressure formations to prevent a blowout, that is the forcing of the fluid out of the hole by the pressure of the formation and the uncontrolled production of fluid from the formation. When a pipe, such as a drill pipe or other pipe, having a bit, a drill stem test device, or other tool attached thereto, is removed from the well, it is necessary to add drilling fluid to replace the volume of the pipe removed. Ordinarily this is a relatively simple operation and can be accomplished merely by starting the rig mud pump occasionally, as the pipe is removed, to supply mud to the hole. If a relatively small pump is available, the pump can be allowed to run continuously to provide mud continuously and let it overflow to the mud tank. However, a danger in such an operation is that the pipe, a drill collar, or the tool attached to the lower end of the pipe will lift mud as it is raised, permitting the space below to be filled with relatively light fluids from the formation. This occurrence is often called swabbing the hole. When this occurs a dangerous situation develops, even though the level of the drilling fluid is maintained at the surface of the ground since, when enough of the hole has been permitted to fill with the light fluid that the total weight of the column is less than the pressure exerted by the fluids from the underground formation, the entire column can be lifted and the blowout occur even though the level of the drilling fluid was at the surface of the ground.

An object of our invention is to detect incipient blowout conditions.

Another object of our invention is to prevent a blowout.

Another object of our invention is to maintain a well bore full of drilling fluid as the equipment is removed from the bore hole.

Another object of our invention is to detect when there is not sufficient drilling fluid in the hole to completely fill it.

Other aspects, objects and the advantages of our invention are apparent in the written description, the drawing and the claims.

According to our invention, sufficient drilling fluid is added to the well bore as equipment is withdrawn from the bore to maintain the level of fluid near the top of the well, that is near the upper end of the well casing, whether at or above the actual surface of the ground, but the addition of excess fluid, that is fluid in an amount sufficient to overflow the well bore, is avoided. This is accomplished by detecting the presence of well fluid at a desired level and adding fluid to the well bore when the level of the fluid drops below the detecting level and discontinuing the addition when the level rises to the desired point. The amount of drilling fluid added is recorded and compared with the amount of drill pipe removed. Either the total amount of fluid added can be recorded and compared with the total amount of pipe removed, or an incremental amount added, recorded and compared with the corresponding amount of pipe removed. For example, the amount recorded for each stand of pipe removed, an amount which should be a recurring constant, can be recorded. In the latter instance the recorder for the amount of fluid added can be reset to zero responsive to a predetermined amount of pipe pulled, as for example the previously-mentioned stand of pipe.

Blowout can be prevented when an incipient blowout is indicated, by an indication of swabbing, that is a reduction in the amount of mud added as compared with the amount of pipe removed, by reducing the speed of pulling to permit compensating flow of mud past the drill bit or other tool or a constricting volume of underground formation around the bit or tool; the pipe can be moved up and down to remove a built-up restriction; or the pipe can be run back in the hole, the circulation system connected and large quantities of mud circulated to remove the low-density down-hole fluid from the well bore.

Apparatus according to our invention for providing means for continuous comparison of the total amount of fluid added with the total amount of pipe removed includes means to determine the amount of pipe removed from the well, as for example by recording the number of stands pulled or by automatically tallying the length of pipe, etc., means to detect the presence of drilling fluid at a predetermined level in the well, means for pumping drilling fluid into the well as needed when the fluid is below the level to return the height of the fluid to this level, means to measure drilling fluid added to the well, means to record the amount of pipe removed from the well, and means to record the amount of drilling fluid added to the well.

The drilling fluid is supplied to the well by a pump and control of the fluid added is by means of controlling the driving means for the pump responsive to the level detecting means.

Where the amount of fluid added is being recorded as a function of relatively small increments of the pipe removed, means are provided as before to detect the presence of drilling fluid at a level near the top of the well, and a pump to supply drilling fluid to the well, driving means for the pump and control means for the driving means acting in response to the level detecting means to maintain the height of the fluid in the well are used as before. Here again, means are provided to measure the drilling fluid added to the well and to record the amount added and, in addition, means are provided to reset the drilling fluid recording means to zero responsive to removal of a predetermined amount of pipe from the well. When the reset is accomplished responsive to each stand pulled, the reset means can include means responsive to the application of the pulling force.

In the drawing, FIGURE 1 is a schematic illustration of apparatus for recording the amount of fluid added and the number of stands of pipe removed.

FIGURE 2 is a schematic circuit diagram for electrical components of the apparatus of FIGURE 1.

FIGURE 3 is a schematic illustration of apparatus for recording the amount of drilling fluid added and resetting the recorder each time a stand of pipe is removed.

FIGURE 4 is a schematic circuit diagram for electrical components of the apparatus of FIGURE 3.

FIGURE 5 is a schematic illustration of another apparatus for recording the amount of drilling fluid added and resetting the recorder each time a stand of pipe is removed.

FIGURE 6 is a schematic illustration of a recorder chart from the apparatus of FIGURE 5.

In the apparatus illustrated in FIGURE 1 and FIGURE 2, the upper end of the well bore is represented by casing 11 on which is mounted a blowout preventer 12, a mud flow nipple 13, and flow line 14. The upper end of the drilling string extends above the upper end of the casing as indicated by a kelly 16. When the drill string is being pulled out of the hole to change the drilling bit, or for other reasons, the drilling fluid is maintained at the desired predetermined level, represented by level 17. A diaphragm transmitter 18 is connected into the side of flow nipple 13, about blowout preventer 12. Transmitter 18 receives supply air through pipe 19 and the output is connected with a pressure controller 21 through pipe 22. Controller 21 receives supply air through pipe 23 and its output is connected with the diaphragm operator of a motor valve 26 through pipe 24. Pressure switch 27 is connected with pipe 24. Electric motor 28 is connected with hydraulic pump 29 through a suitable shaft coupling means 31. Suction 32 of pump 29 is connected with reservoir 33 while outlet 34 is connected with pipe 36 to hydraulic motor 37 and with a by-pass line 38. Shut-off valves 39 and 41 are provided in outlet 34 and by-pass 38, respectively, and these valves are normally open in operation. A return line 42 connects the outlet of hydraulic motor 37 with reservoir 33. Motor 37 drives a positive displacement pump 43 through suitable shaft coupling means 44. Coupling means 44 has a magnet 46 attached thereto. Other driving means can be used. For example the rig mud pump can be used to fill the hole and control means used to actuate the engine or motor driving this pump.

Pump 43 has a suction pipe 47 connected with mud tank 48 through a valve 49 which is open in normal operation, and through a discharge line 51, check valve 52 and shut-off valve 53, with casing 11. A flow switch 54 is connected into discharge line 51. A magnetic pickup 56 is positioned adjacent coupling means 44 and is connected with an amplifier 57. Amplifier 57 in turn is connected with a pulse motor 58 which drives a counter 59 through a variable speed reducer 61.

The line 62 is a hydraulic line to the weight indicator from a hydraulic transmitter attached to the fixed end of the hoisting line, equipment commonly found on a drilling rig. Pressure switch 63 is connected with line 62 and completes a circuit to a time delay relay 64 which completes a circuit to the actuating coil of a counter 66. Pressure switch 27 and flow switch 54 are connected in series with an indicator light 67 and a test switch 68 completes a parallel circuit to light 67.

As illustrated in FIGURE 2, the normally closed contact 54*a* of flow switch 54 and the normally open contact 27*a* of pressure switch 27 are connected in a circuit with indicator light 67 while test switch 68 is in a parallel circuit with this light. The coil 64*a* of time delay relay 64 is connected in a circuit with the normally open contact 63*a* of pressure switch 63. The contacts 64*b* of relay 64 complete a parallel circuit to the coil 64*a* while the contacts 64*c* of relay 64 are connected in series with the actuating coil 66*a* of counter 66.

In operation, as drill pipe is removed from the hole, the level 17 of the drilling fluid in flow nipple 13 falls. When this occurs the pressure on pneumatic transmitter 18 is reduced and a signal is transmitted to pressure controller 21, which in turn transmits a corresponding signal to motor valve 26, tending to close this valve. With valve 26 open, and with motor 28 turning pump 29, hydraulic fluid is circulated through by-pass 38 from pump 29 to reservoir 33 with substantially no increase in pressure. As the pressure is increased by closing valve 26, an increased differential pressure is applied from line 36 through motor 37 to return line 42, thus applying a motive force to motor 37 which turns pump 43, transmitting drilling fluid from suction pipe 47 through discharge line 51 into casing 11. The extent of the lowering of level 17 determines the magnitude of the signal transmitted by diaphragm transmitter 18 and thus the magnitude of the signal transmitted by controller 21 and the degree of closing of valve 26. The more valve 26 is closed the higher the pressure which is applied to motor 37 and the faster pump 43 is turned. As the level of drilling fluid again approaches the level 17, the signal from transmitter 18 is gradually reduced and pump 43 gradually slows down and stops with the level at the proper height, thus avoiding any overflow through flow line 14.

As pump 43 is driven by motor 37, shaft coupling means 44 also rotates, thus rotating magnet 46 causing magnetic pickup 56 to transmit low magnitude electrical pulses to amplifier 57. These pulses are amplified and transmitted to pulse motor 58 which drives counter 59 to record the amount of drilling fluid added. Preferably variable speed reducer 61 is adjusted so that the number of counts for the amount of drilling fluid added for one stand of pipe removed is an even multiple, for example 10 or 100.

Each time the drill pipe is lifted a stress is placed in the drilling line, thus causing an increase in the pressure in line 62 which closes pressure switch 63, thus actuating time delay relay 64. The contacts 64*b* close quickly and open after a time delay following the energization of the coil 64*a*. That is, when contacts 63*a* are closed, energizing coil 64*a*, contacts 64*b* immediately close but open, even with coil 64*a* energized, following a given period of time, the time delay of the relay. The contacts 64*c* have no time delay, being closed when coil 64*a* is energized and released when the coil is de-energized. Thus, when a pressure surge reaches switch 63, relay 64 is energized and is maintained energized at least for the time delay period of the contact 64*b*, even though there may be fluctuations in the pressure in line 62. This makes certain that only a single counting pulse is transmitted by the contacts 64*c* for each joint or stand of pipe lifted, even though there may be some bouncing and fluctuation in pressure when the pipe is picked up and when it is set in the slips. The time delay of relay 64 is long enough to permit pulling a complete stand and setting the pipe on the slips again. From this time until another stand is lifted, there will be no pressure surge in line 62 sufficient to actuate switch 63.

If, for example, the speed reducer is adjusted so that 100 counts of mud volume are recorded for each stand of pipe removed, it is very simple for the driller to compare the amount of mud added with the amount of pipe removed, and when the amount of mud falls below the normal value to check for possible swabbing of the hole.

Light 67 normally will not light unless the pressure in line 24 is sufficient to close the contacts 27*a* of pressure switch 27 and there is no mud flow past flow switch 54. Since the actuating signal in line 22 and line 24 is a reduction in pressure due to the reduction in height of mud over diaphragm transmitter 18, the normal, fully-filled condition is with a relatively high pressure in line 24, thus keeping the contacts closed. This is an indication to the driller that sufficient mud level exists in the casing of the well bore, and pump 43 has stopped. Hoisting is not begun again until this height of fluid has been reached.

If for any reason pump 43 should run longer than necessary to reach the desired mud level, for example sufficient to overflow through pipe 14, light 67 will not light even though the level is high enough to close contacts 27*a* since flow switch 54 is actuated by flow in discharge line 51 to open contacts 54*a*. This avoids a possible erroneous reading since the mud recorded might be thought in the well when actually it has been returned to the mud tank.

In the apparatus of FIGURE 3 and FIGURE 4 the entire automatic fill system and indicator light circuit are the same as illustrated in FIGURE 1 and therefore are not shown in this figure. Instead of feeding the pulses

from amplifier 57 to pulse motor 58, however, these pulses are fed to a stepping switch 71. One bank of contacts of stepping switch 71 is utilized as a potentiometer, as illustrated by the numeral 72 (FIGURE 4). This potentiometer is connected in series with a recorder 73 to control the position of pen 74. Pressure switch 63 is connected in series with a time delay relay 76. Relay 76 has contacts 76*a* which close immediately upon energization but open upon the expiration of the time delay period whether or not relay 76 is energized further. Normally open contacts 76*b* close immediately when relay 76 is energized and open immediately when it is de-energized. Normally closed contacts 76*c* are slow to open, giving a relatively short time delay for opening upon the energization of relay 76. Contacts 78 represent a homing vibrator in stepping switch 71, while contacts 79 represent the disconnection of the circuit when the relay reaches the home position, these contacts being a homing switch. Contacts 81 are a schematic representation of means to provide current pulses to stepping switch 71, a function normally provided by the combination of magnetic pick-up 56 and amplifier 57. That is, the electrical pulses in FIGURE 3 are actually supplied by the magnetic pick-up 56 and amplifier 57, but this function is represented schematically in FIGURE 4 with the contacts 81.

In the operation of this embodiment, the operation of pump 43 to supply drilling fluid to well casing 11 actuates magnet 46, magnetic pick-up 56, and amplifier 57 to supply a number of pulses proportional to the amount of fluid added. These pulses drive stepping switch 71, comprising potentiometer 72, to gradually remove resistance from the circuit to recorder 73. This causes pen 74 to move to the right, as illustrated in FIGURE 3, thus drawing an ascending curve on the chart of recorder 73. Each time a stand of pipe is pulled from the well, a pressure surge occurs in line 62, thus actuating pressure switch 63. This completes the circuit to time delay relay 76. Relay 76 is locked in through contacts 76*a* for a period of time sufficient to pull the stand of pipe and return the remaining pipe to the slips, thus avoiding an incorrect measurement due to bouncing or additional pickup during this period. Contacts 76*c* close. With stepping switch 71 in any but the home position, contacts 79 are closed; thus switch 71 is immediately driven to the home position, at which time contacts 79 are open. A short time later, contacts 76*c* open to disable this circuit for the remaining period of time that relay 76 is actuated. Thus, when additional pulses are supplied, represented schematically by the closing and opening of contacts 81, switch 71 is again driven to the right to drive potentiometer 72 and record another ascending curve on the chart of recorder 73. Since each of these curves represents the total amount of drilling fluid added for one stand of pipe removed, each of the curves should be very near to the same height as all the others. When a curve is appreciably lower than the remaining ones, an indication is given that there may be swabbing and preventive action should be taken.

In the apparatus of FIGURE 5 the automatic flow system and indicator light system are the same as indicated in FIGURE 1 and therefore are not shown in this figure. The pulses from magnetic pickup 56, which can be for example a reed switch, are fed to a one-shot multivibrator 86 where the variable width pulses from pickup 56 are converted to constant width pulses. The constant width pulses are transmitted to an integrating amplifier circuit 87 and the output fed to a strip chart recorder. In this system the pulses from the magnetic pickup 56 are converted to an electrical analogue output, the amplitude of which is directly proportional to the number of pulses received. This is the output which is recorded on the strip chart recorder 88. The output is automatically set to zero at the beginning of each pipe stand pulling operation by the contact 89. This contact is actuated by the initiation of the pulling operation by a switch 91. In one preferred embodiment, switch 91 is a pressure switch similar to switch 63 and is connected to discharge a condenser 92 through relay coil 93 which thus actuates the reset switch 89, which is a contact of the relay, momentarily, the circuit being arranged so that the condenser cannot charge until the pressure switch again opens. Since a finite period of time is required to charge the condenser, momentary opening of the pressure switch is not sufficient to actuate the relay. The continuous small flow of current through coil 93 while switch 91 is closed is insufficient to actuate contacts 89. When the mud pump starts, the pulses accumulate, the output increases to a maximum, depending upon the number of pulses occurring during the time the stand of pipe is removed, and the amplitude is recorded on the strip chart. The amplitude of each of these reported lines on the chart is an indication of the number of pulses received.

The sensitivity of the system can be adjusted so that any number of pulses will give a full-scale output. The sensitivity is adjustable by means of varying the integrator time constant or the resistor R_1. The adjustment can be made on the basis of the pipe diameter. The smaller diameter pipe requires less mud, fewer pulses, and thus has a higher output sensitivity.

As illustrated in FIGURE 6, swabbing is indicated when the length of the recorded lines on the chart is shorter than normal.

Reasonable variation and modification are possible within the scope of our invention which sets forth method and apparatus for detecting an incipient blowout when pulling pipe from a well bore and for preventing a blowout.

We claim:

1. A method for preventing blowout of a drilling well while pulling pipe from the well bore, comprising the steps of:
   - continuously determining the amount of pipe removed from the well;
   - continuously monitoring the presence of drilling fluid at a predetermined level in the well;
   - pumping drilling fluid into the well as needed when said fluid is below said level, to return the height of drilling fluid up to said level;
   - measuring the drilling fluid added to the well;
   - recording the amount of pipe removed from the well;
   - recording the amount of drilling fluid added to the well; and
   - adjusting the quantity of mud in the hole so that the pressure of the mud will counteract the pressure in the borehole when less drilling fluid is recorded than the amount necessary to replace the volume of the amount of pipe removed.

2. A method for detecting an incipient blowout of a drilling well while pulling pipe from the well, comprising the steps of:
   - continuously monitoring the presence of drilling fluid at a predetermined level near the top of the well;
   - pumping drilling fluid into the well as needed when said fluid is below said level, to return the height of drilling fluid up to said level;
   - determining the amount of pipe removed from the well;
   - recording the amount of fluid added as a function of the volume of the amount of pipe removed; and
   - adjusting the quantity of mud in the hole so that the pressure of the mud will counteract the pressure in the borehole when the amount of fluid recorded is less than the amount necessary to replace the volume of the amount of the pipe removed.

3. A method for detecting an incipient blowout of a drilling well while pulling pipe from the well, comprising the steps of:
   - continuously monitoring the presence of drilling fluid at a predetermined level near the top of the well;
   - pumping drilling fluid into the well as needed, respon-

sive to a lowering of the liquid level, to return the height of drilling fluid up to said level;
recording the amount of fluid added;
resetting the recorder for the amount of fluid to zero responsive to a predetermined amount of pipe pulled; and
adjusting the quantity of mud in the hole so that the pressure of the mud will counteract the pressure in the borehole when the amount of fluid recorded is less than the amount necesary to replace the volume of the amount of pipe removed.

4. The process of claim 3 wherein the recorder is reset as each stand of pipe is pulled.

5. Means for detecting an incipient blowout of a drilling well, while pulling pipe from the well, comprising:
means to determine the amount of pipe removed from the well;
means to monitor the presence of drilling fluid at a predetermined level near the top of the well;
means for pumping drilling fluid into the well as needed when said fluid is below said level, to return the height of said fluid up to said level;
means to measure the drilling fluid added to the well;
means to record the amount of pipe removed from the well; and
means to record the amount of drilling fluid added to the well.

6. Means for detecting an incipient blowout of a drilling well, while pulling pipe from the well, comprising:
means to determine the amount of pipe removed from the well;
liquid level monitoring means communicating with said well near the top thereof;
a pump to supply drilling fluid to said well;
driving means for said pump;
control means for said driving means to actuate said driving means as needed responsive to said liquid level detecting means, when said fluid is below said level, to return the height of said fluid up to said liquid level;
means to measure the drilling fluid added to the well; and
means to record the amount of drilling fluid added.

7. Means for detecting an incipient blowout of a drilling well, while pulling pipe from the well, comprising:
means to monitor the presence of drilling fluid at a predetermined liquid level near the top of the well;
a pump to supply drilling fluid to said well;
driving means for said pump;
control means for said driving means to actuate said driving means as needed responsive to said level detecting means, when said fluid is below said liquid level, to return the height of said fluid up to said liquid level;
means to measure the drilling fluid added to said well;
recording means to record the amount of drilling fluid added; and
means to reset said recording means to zero responsive to removal of a predetermined amount of pipe from said well.

8. Apparatus for maintaining a drilling well full of drilling fluid and detecting an incipient blowout of said well, comprising:
a diaphragm transmitted to monitor the presence of drilling fluid at a predetermined level near the top of the well;

a positive displacement pump to supply drilling fluid to said well;
a hydraulic motor to drive said pump;
a hydraulic pump;
an electric motor to drive said hydraulic pump;
conduit means to supply hydraulic fluid from said hydraulic pump to said hydraulic motor;
a reservoir for said hydraulic fluid;
a by-pass to return hydraulic fluid from said hydraulic pump directly to said reservoir;
a motor valve in said by-pass;
a pressure controller to control said motor valve responsive to the pressure from said diaphragm transmitter to actuate said hydraulic motor as needed, when said drilling fluid is below said predetermined level, to raise the height of said fluid up to said level;
means to produce electrical pulses responsive to the speed of said positive displacement pump;
a pulse motor driven by said electrical pulses;
a variable speed reducer driven by said pulse motor;
a first counter driven by said speed reducer;
a pressure transmitter actuated by the stress in a pipe hoisting cable, to increase the pressure transmitted when said stress increases;
a pressure switch connected with said pressure transmitter to actuate a time delay relay when said pressure increases; and
a second counter actuated by said time delay relay.

9. Means for detecting an incipient blowout of a drilling well, while pulling pipe from the well, comprising:
means to monitor the presence of drilling fluid at a predetermined level near the top of the well;
a pump to supply drilling fluid to said well;
driving means for said pump;
control means for said driving means to actuate said driving means as needed responsive to said level detecting means, when said fluid is below said level, to return the height of said fluid up to said level;
means to measure the drilling fluid added to said well comprising means for producing electrical pulses proportional to the rate of addition of drilling fluid being added;
a pressure transmitter actuated by the stress in the pipe hoisting cable to increase the pressure transmitted when said stress increases;
a pressure switch connected with said pressure transmitter to actuate a time delay relay when said pressure increases;
a pair of instantaneously closing, time delay opening contacts in said relay in parallel with said pressure switch;
a stepping switch;
a pair of instantaneously closing and instantaneously opening, normally open contacts and a pair of slow-to-open and slow-to-close normally closed contacts actuated by said relay and connected in series with the homing circuit of said stepping switch; and
means to supply said electrical pulses to the pulsing circuit of said stepping switch.

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