United States Patent [19]

Leonard

[11] 3,729,986

[45] May 1, 1973

[54] **MEASURING AND SERVICING THE DRILLING FLUID IN A WELL**

[76] Inventor: **Loren W. Leonard,** 8345 Triola, No. 33, Houston, Tex. 77036

[22] Filed: **July 29, 1971**

[21] Appl. No.: **167,194**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 67,706, Aug. 28, 1970, Pat. No. 3,646,808.

[52] **U.S. Cl.** **73/155,** 166/250

[51] **Int. Cl.** **E21b 47/10**

[58] **Field of Search** ....346/33 WL; 73/152, 73/151.5, 155; 166/250

[56] **References Cited**

UNITED STATES PATENTS

3,614,761 10/1971 Rehm et al. ....73/155 X

2,832,566 4/1958 Bielstein ....73/155 X

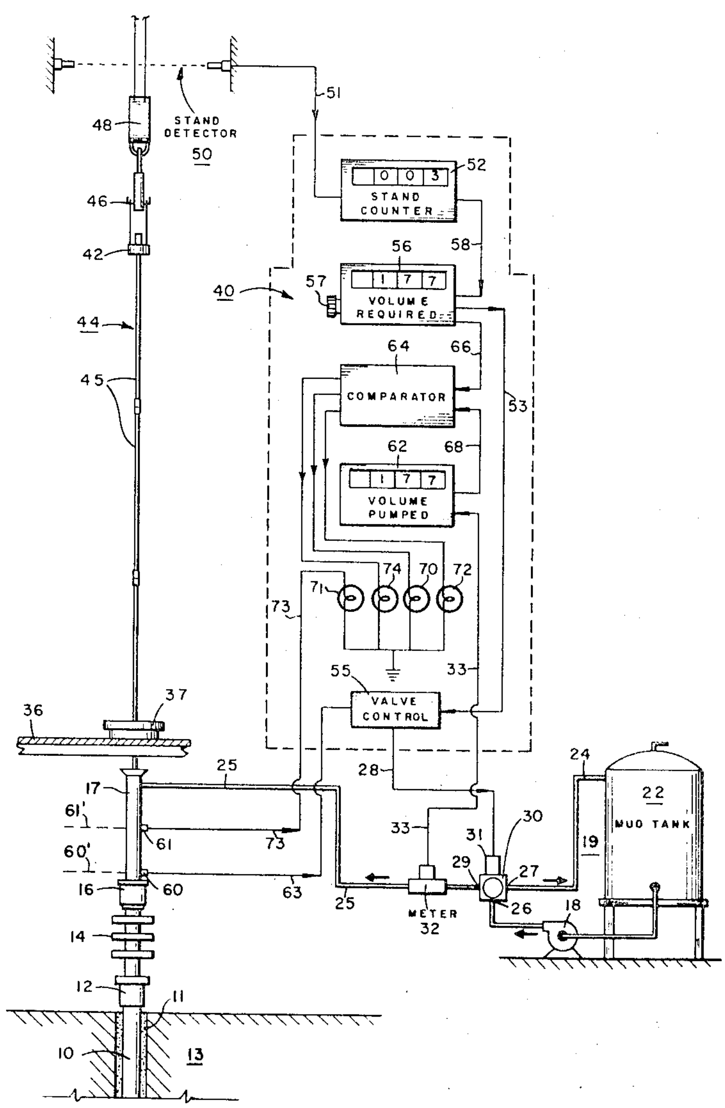
Primary Examiner—Jerry W. Myracle

Attorney—Michael P. Breston

[57] **ABSTRACT**

This invention relates to a method and system for detecting the condition of a well. During tripping the drilling fluid in the well is controlled to provide an early warning indication of an abnormality in the well. The volume of solid materials moved during each trip is measured and a corresponding required volume of drilling fluid is determined. A measured volume of drilling fluid is delivered in order to restore in the well the drilling fluid to a reference level. The required volume is compared with the measured volume to obtain signals which are indicative of the condition of the well.

11 Claims, 2 Drawing Figures



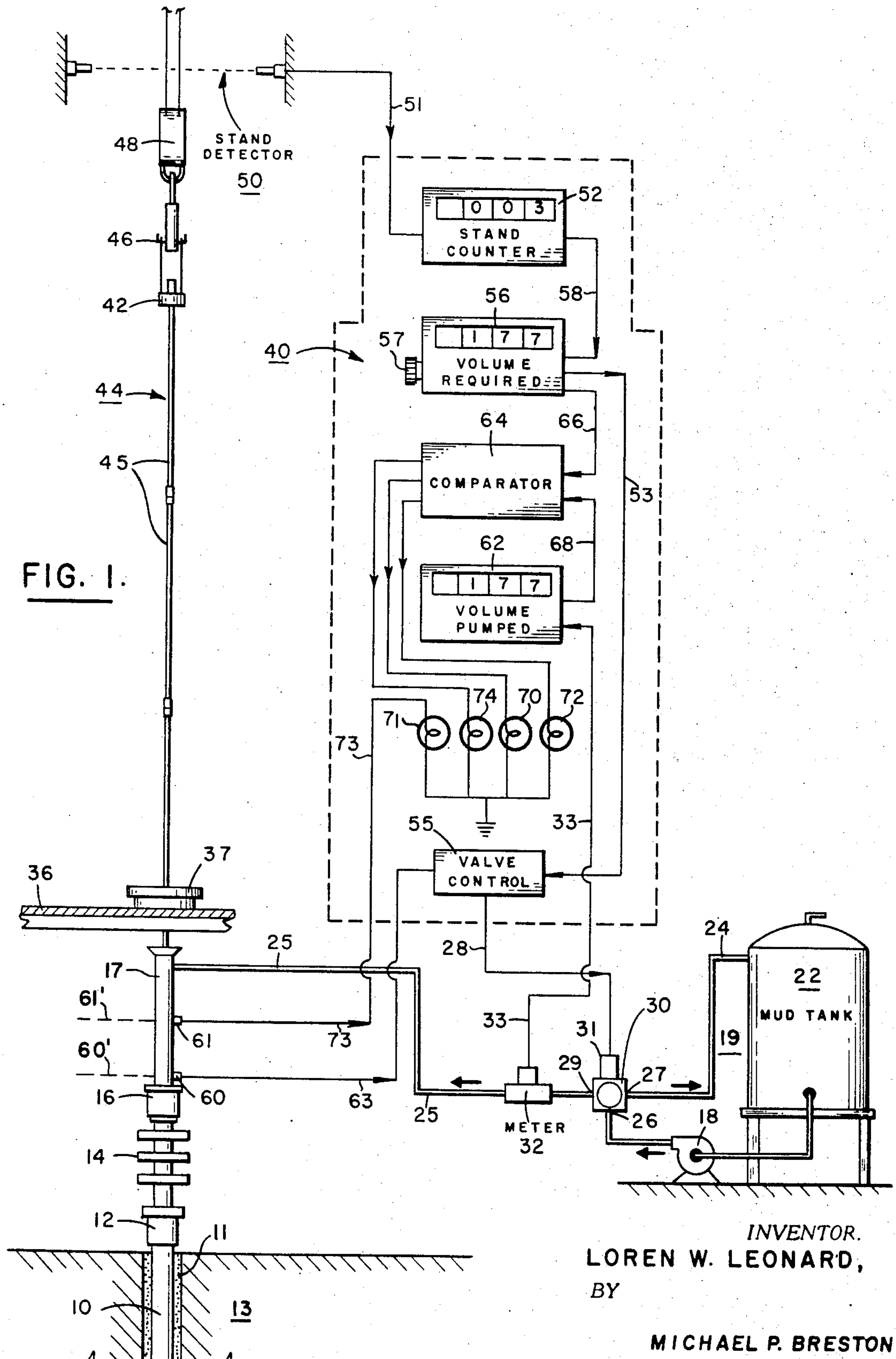


FIG. 1.

INVENTOR.
LOREN W. LEONARD,
BY
MICHAEL P. BRESTON
ATTORNEY.

Patented May 1, 1973 3,729,986

2 Sheets-Sheet 2

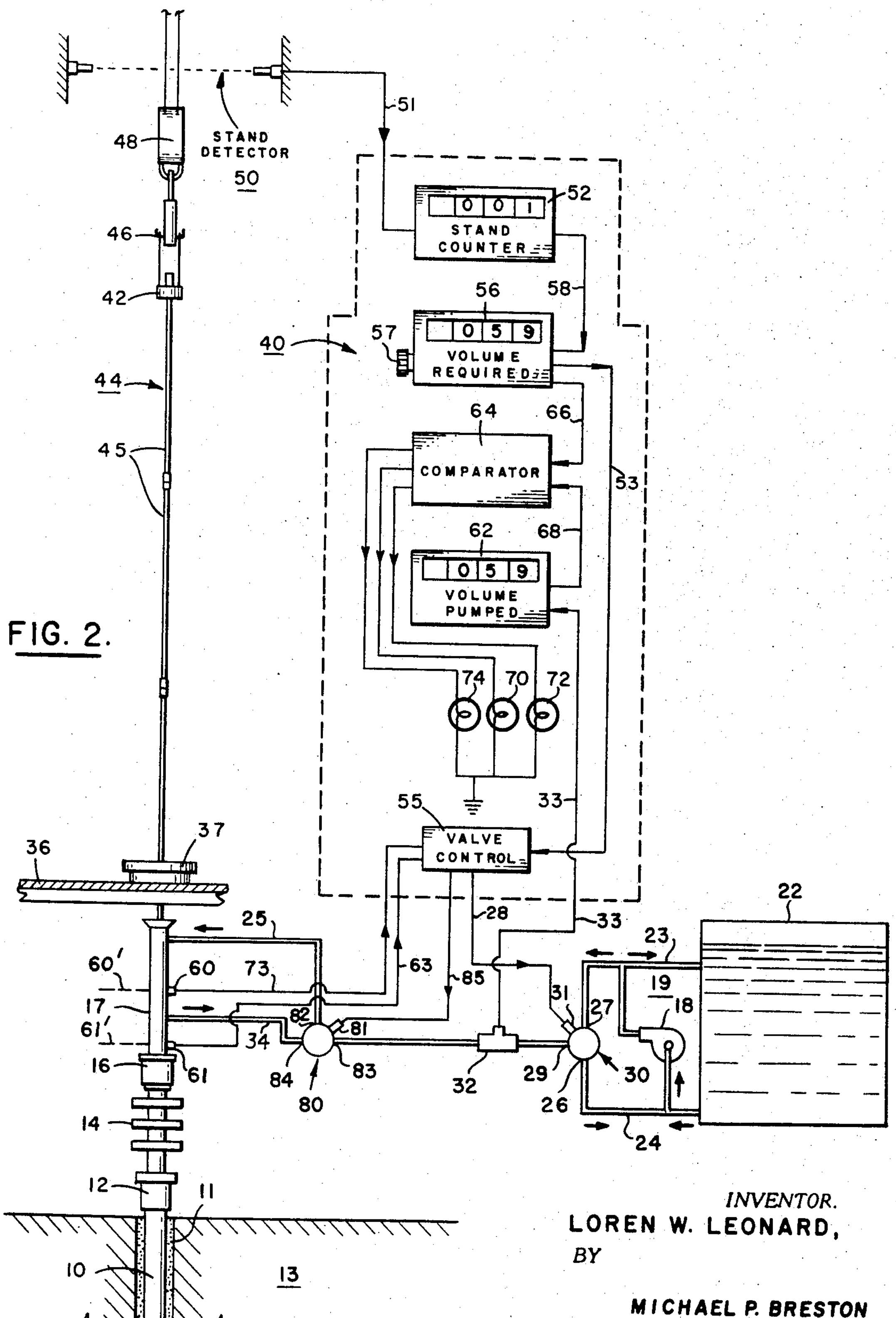


FIG. 2.

INVENTOR.
LOREN W. LEONARD,
BY
MICHAEL P. BRESTON
ATTORNEY.

MEASURING AND SERVICING THE DRILLING FLUID IN A WELL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of applicant's application Ser. No. 67,706 filed Aug. 28, 1970 now U.S. Pat. No. 3,646,808.

BACKGROUND OF THE INVENTION

Well bores are typically drilled through a geologic formation of several layers. It is anticipated that each such layer will exert a normal pressure on the drilling fluid in the well bore. Those layers containing fluids such as gases, hydrocarbons, water, salt water, etc., can on occasion exert an abnormal pressure on the drilling fluid in the well bore. The density of the drilling fluid should be such as to provide a hydrostatic pressure which will prevent formation fluid intrusion into the bore, but not sufficiently great as to cause a formation breakdown.

If the pressure of the fluids contained in a particular formation layer becomes excessive, or if the hydrostatic drilling fluid pressure drops appreciably, then there will be an intrusion of the formation fluid into the well bore. Such an intrusion will augment and contaminate the volume of drilling fluid in the well bore. In the event of a formation breakdown, drilling fluid is lost to the formation. A loss of drilling fluid results in a lowering of the hydrostatic pressure head.

When this loss becomes appreciable, the pressure head of the drilling fluid will no longer withstand even the normal formation pressure. In that event, if high-pressure fluids exist in the formation, they will intrude into the well bore. Thus, an original loss of drilling fluid into the formation can produce a formation fluid intrusion into the well bore. A low-volume intrusion is generally known as a "kick", and a large-volume intrusion as a "blowout".

It has been observed that when drilling a well bore, the majority of blowouts occur while "tripping", which is an act of moving a pipe string in or out of the well bore, for example to replace drill bits, remove obstructions, perform logging operations, etc. An "insertion trip" is an act of inserting a volume of solid material, such as pipe joints and drill collars, into the well bore. A "withdrawal trip" is an act of withdrawing such a volume of solid material from the well bore. A "trip" means a withdrawal trip, an insertion trip, or both.

Traditional and current withdrawal trip procedures require visual counting of the number of moved pipe stands, and the filling of the well bore up to a level from which drilling fluid can flow out of the bore. This procedure has certain drawbacks which, in the extreme, can destroy operating personnel, petroleum reserves, drilling equipment, and can cause serious ecological damage. In particular, this procedure is not sufficiently accurate, and above all is subject to human error. For example, if a low-volume gain or loss in drilling fluid is not timely detected, it may become a large-volume gain or loss. If a blowout is to be positively averted, drilling fluid gains or losses must be detected preferably soon after they occur in order to allow for remedial steps to be effectively undertaken.

It is a broad object of this invention to provide a method and system for automatically maintaining while tripping the drilling fluid in a well bore at or near a reference level, and to provide an early warning indication of the existence of an abnormality in the drilling fluid condition. Also, the drilling fluid level in the well bore is continuously and automatically monitored during a trip and subsequent thereto.

The invention can be carried out by relatively-unskilled personnel and within a minimum of time, thereby substantially reducing the cost as well as the potential hazard of the drilling operation. The invention allows the drilling crew to attend to chores other than those connected with moving drilling fluid into or out of the well bore.

SUMMARY OF THE INVENTION

This application describes subject matter claimed in said copending application and additionally describes and claims a method and system for detecting the condition of a well by controlling, while inserting drill pipe into a well, the drilling fluid in the well, thereby providing an early warning indication of an abnormality in the well. A count is made of the units of solid materials inserted into the well to obtain a required volume of drilling fluid to be delivered from the well. A measured volume of drilling fluid is then delivered from the well in order to restore in the well the drilling fluid to a reference level. The required volume and the measured volume as compared, and from the results of the comparison signals are obtained which are indicative of the condition of the well.

If fluid is being lost to the formation after a trip, the invention also contemplates automatically delivering drilling fluid to the well bore in an attempt to restore the hydrostatic pressure head and to thereby avert a possible blowout.

In a preferred system of a trip controller of the invention, a count is made of the number of pipe stands moved during each trip. This count is multiplied by a suitable scaling factor, depending upon the physical characteristics of the pipe stands, in order to obtain the required volume of drilling fluid for the well bore. This required volume is then compared with a metered volume of the actually delivered drilling fluid in order for the drilling fluid in the well bore to reach its normal reference level. This comparison automatically provides an indication of the drilling fluid condition in the well bore.

The invention will be better understood with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic representation of a controller used in connection with a withdrawal trip; and

FIG. 2 is a diagrammatic representation of a controller which can be used either for a withdrawal trip or for an insertion trip.

CONTROLLER FOR WITHDRAWAL TRIP

FIG. 1 illustrates a conventional well **11** being drilled through a formation **13**. Well **11** typically includes a casing **10**, a well head **12**, surface blowout preventers **14** and **16**, and a bell nipple **17**. A surface drilling fluid circulating system **19** includes a pump **18** which circulates the drilling fluid in a tank or pit **22** through a fluid line **24**. Pump **18** is a low-pressure, high-volume pump in comparison to the high-pressure, high-volume, extremely-bulky stroke pump (not shown), conventionally employed to fill the well bore. A fill line **25** is connected to a suitable valve **30** having ports **26**, **27** and **29** and a control element **31**. Ordinarily, valve **30** maintains fluid flow in line **24** through normally-open ports **26** and **27**. When element **31** becomes actuated by a power line **28**, valve **30** will close ports **26** and **27** and establish fluid communication between its normally-closed ports **26** and **29**.

To measure the volume of fluid pumped and delivered into the well bore, there is provided in fill line **25** a fluid meter **32** whose readout is preferably an electric signal fed via line **33** to a volume-delivered counter **62**. Such fluid flow meters are manufactured, for example, by the Foxboro Company in the U.S.A. and are known as magnetic or turbine flow meters.

Mounted on the derrick floor **36** are a conventional rotary table **37** and a trip controller **40** which is shown enclosed in a dotted-line box. Controller **40** is preferably a digital system for it provides faster response and greater versatility. It will be understood, however, that an analog rather than a digital system could be equally employed, as will be apparent to those skilled in the art.

Above the derrick floor **36** are the elevators **42** coupled between a drill pipe stand **44**, which it is desired to withdraw, and a hook **46**. Hook **46** is carried by a block **48** in a conventional manner. Each pipe stand **44** normally comprises a number, say three, of drill pipe joints **45**. The pipe stands, drill collars, and auxiliary tools form a conventional drill string.

To count the number of pipe stands **44** withdrawn by block **48** during each trip, there is provided a stand detector **50** which detects the withdrawal of each pipe stand and provides an appropriate electric or pneumatic signal through a line **51** to advance the count in a stand counter **52**. The stand detector **50** is preferably positioned on the side wall of the derrick at a distance of the derrick floor **36** which is approximately equal to the length of a pipe stand. Detector **50** can be a mechanical system, an optical system employing a light beam and photo cells, a pneumatic system, or an electro-mechanical system including microswitches for closing an electric circuit after the passage of each pipe stand **44**.

Whichever system is employed for the stand detector **50**, line **51** can be made to receive a number of signals or pulses equal to the number of pipe stands withdrawn. This number, illustrated as 3, will be displayed in the window of stand-counter **52** as 003.

A volume-required counter **56**, which may be a solid state electronic digital multiplier device, manually receives a scaling factor through a knob **57**. The scaling factor is determined from the physical parameters of the pipe stands being withdrawn. Counter **56** actually multiplies this scaling factor by the count of stands pulled. This count is received on a line **58** from the stand-counter **52**. The count in the window of counter **56** is the volume required for the three stands pulled by the block **48**.

The required fluid volume is the volume of fluid necessary to restore the fluid level in the well bore back to a reference level **60'**. This level is monitored by a "-normal" level detector **60** coupled to bell nipple **17**. The required volume is a volume of fluid necessary to replace the volume of solid material (pipe stands) withdrawn from the well bore.

If the delivered volume of fluid equals the required volume, and the fluid level in the bell nipple **17** is still below reference level **60'**, pump **18** will continue to deliver fluid into the well bore, but an alarm or warning signal will be given as hereinafter described.

If the fluid in the well bore suddenly rises above a high-level **61'**, a "high-level" detector **61** coupled to bell nipple **17** will detect this rise in the level of the drilling fluid and will provide a warning signal.

The count of the delivered volume is displayed in the window of counter **62**. Assuming normal operation, and for a scaling factor of 0.59, the volume delivered will be 1.77 units of volume.

A suitable comparator **64** receives on line **66** the count from the volume-required counter **56**, and on line **68** the count from the volume-pumped counter **62**. Comparator **64** compares the counts received on lines **66** and **68**. In the event that the volume required is substantially equal to the volume delivered, the result will be indicated by a "fluid normal" indicating device **70**. If the volume delivered is greater than the volume required, comparator **64** will provide an output signal to a "fluid loss" indicating device **72**. If the volume pumped is less than the volume required, comparator **64** will provide an output signal to a "fluid gain" or kick indicating device **74**.

Prior to starting the withdrawal trip, the driller selects, in the manner previously described, a suitable scaling factor and inserts it into the volume-required counter **56**. He also selects the number of pipe stands to be pulled during each withdrawal trip and adjusts counter **56** accordingly. Then the withdrawal trip is initiated. Stand detector **50** causes the count in stand-counter **52** to increase by one for each pipe stand withdrawn.

As previously mentioned, at the completion of the withdrawal trip, stand detector **50** will have detected three stands, the count in the window of stand-counter **52** will be 003, and the count in the volume-required counter **56** will be 1.77. Thereafter a signal will be supplied from counter **56** via a line **53** to a valve controller mechanism **55** which actuates via line **28** valve **30** and causes it to establish fluid flow between its ports **26** and **29**. This marks the beginning of the refilling operation through the fill line **25** and the metering operation through the fluid meter **32**. The refilling operation ends when the fluid reaches the reference level **60'**.

Assuming that the refilling operation is normal, after the fluid meter **32** has measured a delivered volume which is equal to the required volume, the fluid level in the well bore will be at the reference level **60'**, as detected by the normal level detector **60**, and the normal lamp **70** will become actuated. If the measured delivered volume is greater than the required volume, comparator **64** will actuate the loss warning light **72**. If the delivered volume is less than the required volume, the kick lamp **74** will become actuated.

After the fluid in the well bore is restored to its reference level **60'**, the normal level detector **60** will provide a signal via line **63** to the valve controller **55** for actuation of valve **30**, thereby stopping fluid flow between its ports **26** and **29** and re-establishing fluid flow between its ports **26** and **27**. Counters **52**, **56** and **62** will then be ready to begin the next withdrawal trip.

If after valve **30** has switched back to its normal condition, whereby fluid flows between ports **26** and **27**, there should occur a sudden rise in the fluid level above the reference level 60′ and up to level 61′, the high-level detector 61 will then provide a signal to a warning light 71 via line 73.

While in the above description specific reference was made to particular component parts and sub-assemblies, it will be appreciated that variations are possible. For example, pump 18 need not be the fluid circulating pump of the fluid pit 22. Instead, a pump independent of the fluid circulation system 19 could be employed for pumping fluid from pit 22 into well bore 11 and, hence, valve 30 could be eliminated. Also, other valves could be employed and other volume measuring means could be used to measure the volume of solid material withdrawn.

To facilitate the understanding of the trip controller shown in FIG. 2, to the extent possible the same numerals were used in both FIGS. 1 and 2. Accordingly, only those elements in FIG. 2 which are either new or different will be specifically described in connection with FIG. 2.

Pump 18 in the surface fluid circulation system 19 circulates the fluid through pit 22 between a suction line 24 and a discharge line 23. In addition to valve 30, there is now provided another valve 80 having ports 82, 83 and 84 and a control element 81. Fluid flow meter 32 is in a line between ports 29 and 83. The fill line 25 and a return flow line 34 connect the bell nipple 17 to ports 82 and 84, respectively.

Whereas in FIG. 1, detector 61 served as a high-level detector, in FIG. 2 detector 61 serves as a low-level detector. The valve controller 55 now has three input lines 53, 63, 73 and two output lines 28 and 85.

WITHDRAWAL TRIP MODE

To illustrate the withdrawal trip mode operation of the trip controller 40 in FIG. 2, assume that counter 52 counts one stand and that 0.59 is the volume of fluid displaced by one pipe stand. The scaling factor to be inserted through knob 57 will be 0.59. Counter 56 will count 059 and emit a signal via line 53 to the valve controller 55. Controller 55 will send a signal via line 28 to valve element 31 and will also send a signal via line 85 to valve element 81. Valve 30 will establish fluid flow between ports 27 and 29, and valve 80 will establish fluid flow between ports 82 and 83. The flow of the drilling fluid then is from pit 22, through pump 18, discharge line 23, valve 30, meter 32, valve 80, and fill line 25.

When the fluid level in the bell nipple 17 rises to the reference level 60′, detector 60 will transmit a signal to valve controller 55 via line 73. This signal will cause valve controller 55 to break fluid flow between ports 82, 83 as well as between ports 27, 29. The delivered volume of fluid as measured by meter 32 will be indicated in the window of counter 62. Assuming normal drilling operation, with no loss or gain in the volume of drilling fluid in the well bore and for the numbers previously given, counter 62 will read 059. Comparator 64 will compare the counts in counters 56 and 62 and will provide signals to lights 70, 72 and 74 in the manner described in connection with the controller of FIG. 1.

INSERTION TRIP MODE

When the controller shown in FIG. 2 is used in its insertion trip mode, each pipe stand 44 lowered into the well bore will again be detected by detector 50. Counter 56 will indicate the volume of fluid which corresponds to the volume of the solid material inserted into the well bore. After counter 52 counts one stand, counter 56 will issue a command signal via line 53 to the valve controller 55. Controller 55 will then establish fluid flow between ports 83 and 84 of valve 80, and between ports 26 and 29 of valve 30.

Whereas in the withdrawal trip mode drilling fluid is delivered from pit 22 into the well bore 11, in the insertion trip mode drilling fluid is delivered from the well bore 11 into pit 22. The volume of drilling fluid flowing out of the well bore into the pit 22 is again measured by the flow meter 32.

With the insertion of solid material into the well bore, the level of the drilling fluid in the bell nipple 17 rises above reference level 60′. Therefore, the delivery of drilling fluid from the well bore will continue until the level of the fluid in bell nipple 17 drops to the reference level 60′. Then, detector 60 will transmit a signal via line 73 to the valve controller 55 which will stop fluid flow between ports 82, 83 and between ports 26, 29.

The delivered volume of fluid from the well bore to pit 22, as measured by meter 32, will be counted by counter 62. The counts in counters 56 and 62 will again be compared by comparator 64 and the results of that comparison will again be indicated by lights 70, 72 and 74.

AUTOMATIC MAINTAIN MODE

In addition to serving as a trip controller, the system shown in FIG. 2 can automatically maintain the drilling fluid level in the well bore above a minimum level 61′ as detected by the low-level detector 61. In this automatic maintain mode, when the drilling fluid level drops below level 61′, a command signal is issued by detector 61 via line 63 to valve controller 55. Controller 55 will then allow fluid flow between ports 28, 29 and ports 82, 83. In this manner fluid will flow from the discharge line 23 into the fill line 25 and down into the well bore 11.

This flow will continue until the level of the drilling fluid in the bell nipple 17 is raised back to the minimum level 61′. Then, detector 61 will cause valve controller 55 to stop fluid flow between ports 27, 29 and ports 82, 83.

Again, it should be understood that the trip controller 40 shown in FIG. 2 will lend itself to modifications, as will be apparent to those skilled in the art.

What is claimed is:

1. A system for detecting the condition of a well by controlling, while inserting solid materials into the well, the drilling fluid in said well and providing an early warning indication of an abnormality in said well, comprising:

- means for measuring a required volume of drilling fluid corresponding to a volume of solid materials moved into the well during each trip;
- means for delivering from the well a measured volume of drilling fluid in order to restore in the well the drilling fluid to a reference level; and

means including comparing means for comparing said required volume with said measured volume to obtain said early warning indication.

2. The system of claim 1 wherein said well includes a bell nipple and said reference level is monitored in said bell nipple.

3. The system of claim 2 wherein said means for delivering include a fluid flow meter.

4. The system of claim 3 wherein said means for measuring include:

a first counter for counting the units of said solid materials moved; and

a second counter responsive to said first counter, said second counter providing an indication of said required volume.

5. The system according to claim 4 wherein said means for delivering includes a circulating pump associated with the drilling fluid's surface circulation system.

6. A system for detecting the condition of a well by controlling, while tripping, the drilling fluid in said well and providing an early warning indication of an abnormality in said well, said system comprising:

means for measuring a required volume of drilling fluid corresponding to a volume of a number of

pipe stands moved during each trip;

means for delivering a measured volume of drilling fluid in order to restore in the well the drilling fluid to a reference level; and

means including comparing means for comparing said required volume with said measured volume to obtain said early warning indication.

7. The system of claim 6 wherein said well includes a bell nipple and said reference level is monitored in said bell nipple.

8. The system of claim 7 wherein said means for delivering include a fluid flow meter.

9. The system of claim 8 wherein said means for measuring include:

a first counter for counting the number of said pipe stands moved, and

a second counter, responsive to the output of said first counter, for providing an indication of said required volume.

10. The system of claim 8 wherein said means for delivering and further including a circulating pump.

11. The system of claim 8 wherein said flow meter is a turbine flow meter.

* * * * *