

United States Patent [19]

Guest

[11] 3,841,152
[45] Oct. 15, 1974

[54] DRILLING CONDITIONS MONITOR

[75] Inventor: Robert J. Guest, Duncan, Okla.

[73] Assignee: Halliburton Company, Duncan, Okla.

[22] Filed: Feb. 2, 1973

[21] Appl. No.: 329,147

[52] U.S. Cl. 73/151

[51] Int. Cl. E21b 47/06

[58] Field of Search 73/151, 152, 391, 393;
346/33 W, 66

[56] References Cited

UNITED STATES PATENTS

2,818,726	1/1958	Amonette et al.	73/391 X
3,389,397	6/1968	Lex, Jr. et al.	346/66 X
3,490,150	1/1970	Whitfill, Jr.	73/151 X
3,540,285	11/1970	Nicolau et al.	73/392

FOREIGN PATENTS OR APPLICATIONS

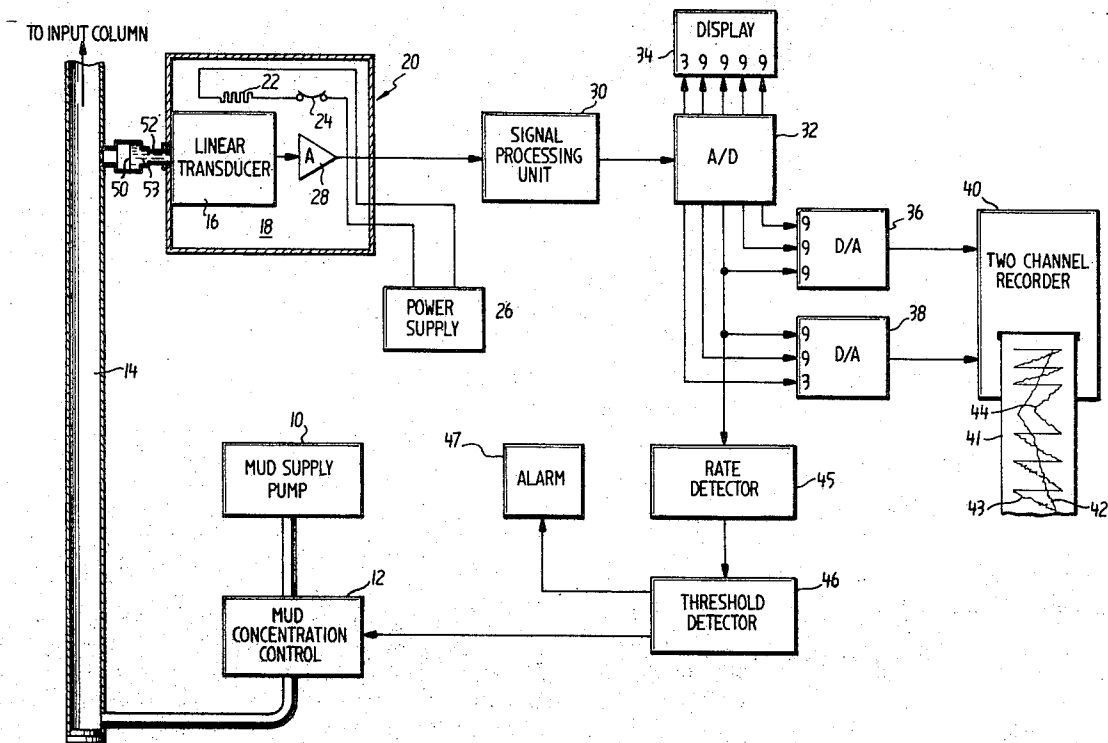
1,055,350	2/1954	France.	73/393
-----------	--------	--------------	--------

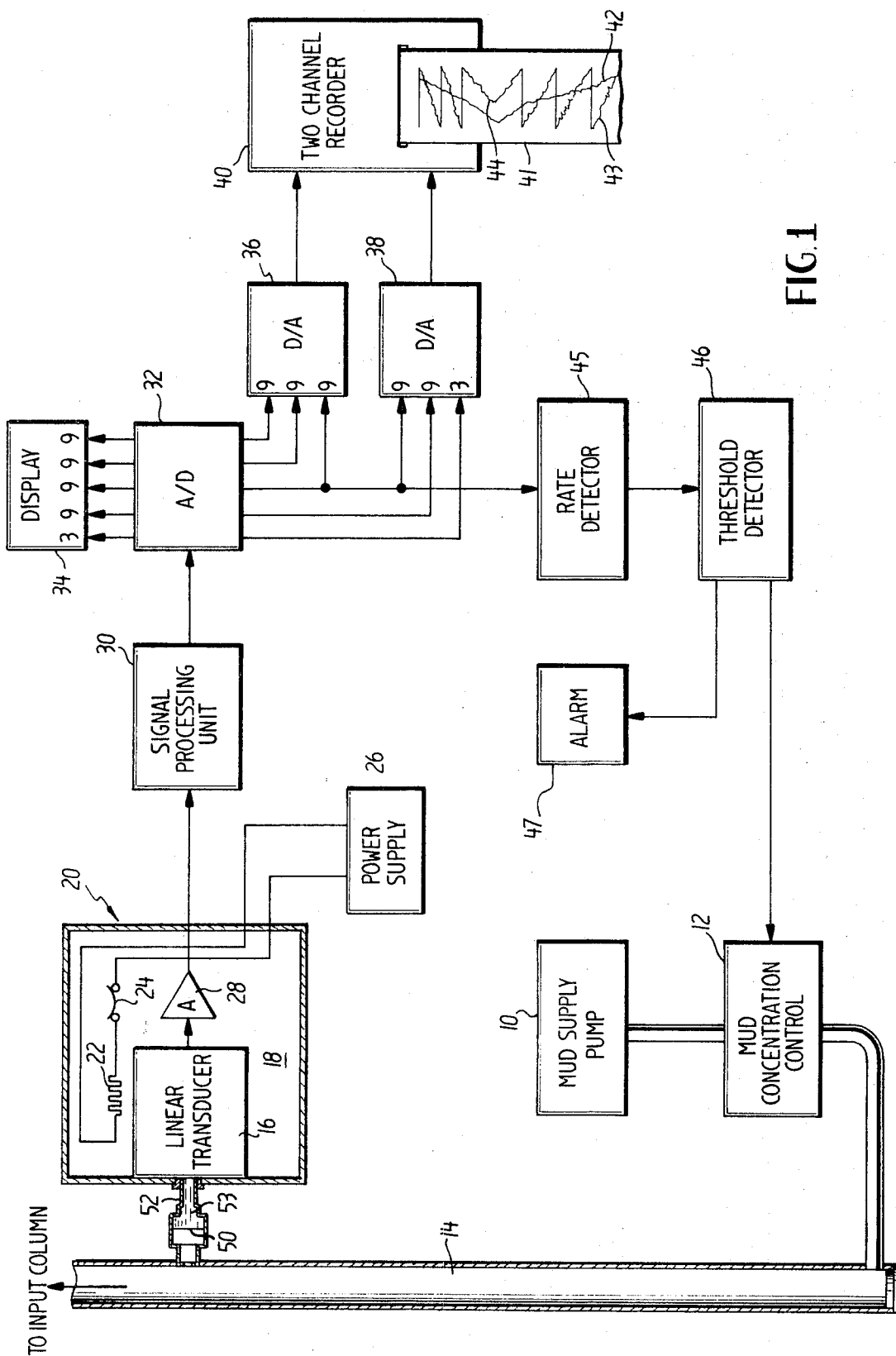
Primary Examiner—Jerry W. Myracle
Attorney, Agent, or Firm—L. Lawton Rogers, III;
Floyd A. Gonzales; John H. Tregoning

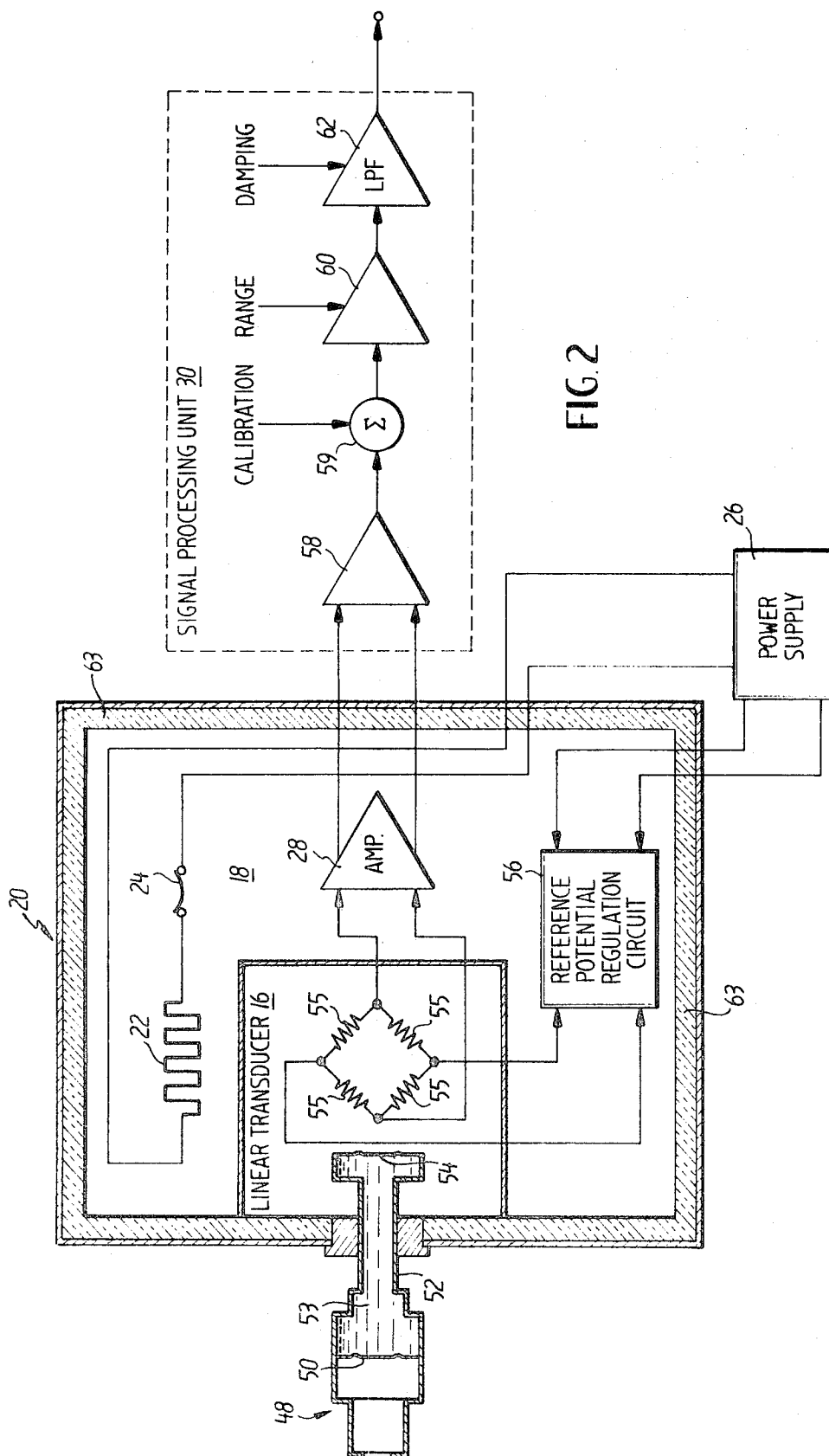
[57] ABSTRACT

A drilling fluid pressure recording system which produces a digital readout and a dual trace on a chart strip recorder which has a design accuracy of ± 4 psi for up scale recording to 4,000 psi full scale. An analog electrical signal is converted into a five order digital signal and the digits reconverted back into two analog signals that are displayed on a dual pen strip chart recorder to provide both coarse and fine traces of the pressure. With both traces on the same chart, the result is a chart record that can be interpreted very accurately at the driller's console.

5 Claims, 2 Drawing Figures







DRILLING CONDITIONS MONITOR

BACKGROUND OF THE INVENTION

This invention relates to the monitoring of a drilling fluid circulating in a wellbore, and more particularly to a method and apparatus for detecting fluid pressure with sufficient precision to enable the driller to detect a "kick" shortly after it occurs and to take corrective action to prevent a well blowout.

It is standard practice in well drilling to circulate a drilling fluid such as drilling mud through the wellbore in coaxial fashion. The hydrostatic pressure resulting from the mud weight controls the well formation pressure, with the mud weight adjusted as required. However, when drilling into high pressure gas, the sudden gas pressure exerts a force which tends to lift the mud in the output column of the drilling rig. The lifting of the mud in the output column is referred to as a well "kick". The onset of a "kick" is subtle and its detection during its early stages is difficult.

It will be appreciated that as the undetected "kick" progresses, it is harder to control. The terminus of an uncontrolled "kick" is commonly a disastrous well "blowout." As the "kick" progresses, a small high pressure gas pocket entrained in the mud travels upwardly. As the high pressure gas pocket travels upwardly, the pocket is subject to less hydrostatic pressure and displaces an increasingly greater volume of heavier mud. Therefore, the output column becomes lighter and a pressure drop occurs in the output column.

While the pressure drop is large in the final stage of a blowout, the pressure drop is very small and virtually undetectable during the initial stages. It will therefore be appreciated that if the minute pressure change which occurs in the input column at the very early stage of a "kick" is detected with sufficient accuracy and reliability, the onset of a well "kick" may be quickly confirmed and measures taken to prevent a blowout.

One object of the present invention resides in providing a high pressure sensing system capable of handling the 4,000 psi pressures encountered when drilling which is also capable of providing a reliable indication of minute pressure changes on the order of a fraction of one psi which precede a blowout, and yet distinguish the other minute pressure changes unrelated to the onset of a "kick," such as perturbations originating in the mud circulation equipment.

It is a further object of the invention to provide a novel method and apparatus for detecting and for continuously displaying at the driller's console the instantaneous mud pressure as well as a chart record to provide an easily recognizable indication of a well "kick."

It is another object to provide a novel recording and display method and apparatus for sensing minute changes in drilling fluid pressure with perturbations in the sensed pressure due to the fluid circulating pumps removed from the pressure signal to facilitate the early detection of "kicks" to enable steps to be taken to prevent blowouts.

These and other objects of the present invention will become apparent to one skilled in the art to which the invention pertains from the claims and from a perusal of the following detailed description when read in conjunction with appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of a high resolution pressure recording system having a pressure transducer installed in the standpipe of a drilling fluid circulation system; and

FIG. 2 is a schematic block diagram further illustrating the transducer assembly and signal processing circuits of the system of FIG. 1.

DETAILED DESCRIPTION

Referring to FIG. 1, in a typical drilling operation drilling fluid is pumped from a mud supply pump 10 through a mud concentration control unit 12 into a standpipe 14 simultaneously with the pumping of mud to the wellbore. The pressure of the mud in the standpipe 14 or other suitable location in the drilling fluid supply pipes may be sensed by a linear transducer 16 within a chamber 18 of housing 20. To maintain the temperature in housing 20 constant, an electrical heating element 22 in series with a thermostat 24 is connected to a power supply 26 which may be located outside and remote from the housing 20.

An amplifier 28 is preferably located within the chamber 18 to amplify the output signal from the linear transducer 16. Both transducer 16 and amplifier 28 are made of components that are temperature sensitive. Because of the variations of temperature encountered at the wellhead and the need for high resolution in the pressure sensing system, both transducer 16 and amplifier 28 are preferably located in the temperature controlled housing 20.

The analog electrical output signal from amplifier 28 is processed by a signal processing unit 30 for calibration, range selection, and low pass filtering, to be described hereinafter. The analog electrical signal is then applied to an analog-to-digital converter 32. For a typical drilling installation where the drilling fluid pressures reach 4,000 psi, the analog electrical signal may be converted to a five order digit signal. In the illustrated system, each digit is a binary decimal with four bits per digit and used to drive a suitable digital display 34 in a substantially continuous fashion to display a five digit number representing the sensed pressure to one-tenth psi.

The signals corresponding to the three least and most significant digits of the number representing sensed pressure may be converted to separate analog signals by suitable digital-to-analog converters 36 and 38 with the two analog output signals applied to a two-channel recorder 40. In the illustrated recorder, which may be a conventional two-pen type having a continuously moving chart 41, two time varying traces 42 and 43 are provided. The recorder 40 may include two pens, each responsive to full scale deflection, with different input values so that trace 42 may operate with a full scale deflection of, for example, 4,000 psi, whereas trace 43 will operate with a full scale deflection of 100 psi. In the lower portion of chart 41, traces 42 and 43 represent a gradually increasing pressure. At point 44, a reversal of the pressure change is illustrated which may be indicative of the detection of a "kick." The traces 42 and 43 above point 44 represent a more rapidly decreasing pressure. The two traces together give the drilling operator a visual indication which is easily understood so that he can take remedial steps to prevent a blowout.

Optionally, the digital signal representing one of the least significant digits, such as the third order, may be applied to a conventional rate detecting circuit 44 for detecting the rate of increase or decrease of the drilling fluid pressure. The output signal from the rate detecting circuit 44 may be applied to a threshold detector 46 to produce a signal upon detection of a predetermined rate of decrease indicative of a well "kick." The output signal from the decreases detector 46 may be applied to the mud concentration control unit for automatically altering the mud concentration to prevent a blowout and to actuate an alarm 47.

In operation, the pressure of the drilling fluid circulating in the wellbore equipment is detected and amplified as at the standpipe location. The amplified analog electrical signal is then applied through the signal processing unit to display and/or mud control apparatus. The sensed pressure is continuously displayed in digital form, with changes in pressure being easily recognized by step changes in the least significant digits of the sensed pressure. An operator observing the display 34 can easily recognize minute pressure decreases indicating the onset of a well "kick" and take appropriate preventive action such as modifying the density of the mud supplied to the drilling equipment.

Alternatively, the operator can observe the strip chart 42. One trace thereof indicates "coarse" pressure, i.e., the more significant digits of the number representing sensed pressure. The other trace represents the "fine" pressure i.e., the least significant digits. If the sensed pressure starts to drop, stepped pyramid-like tracings 43 will appear on record 41 to warn the operator of the onset of a well "kick."

The apparatus of FIG. 1, to operate with the desired precision accuracy, needs a pressure sensor having maximum sensitivity. One of the problems in detecting well "kicks" in time to take preventive action is the pressure sensing and processing equipment which desirably operates over a pressure range of 0 to 4,000 psi to an accuracy of a fraction of one psi. With this sensitivity, the short term periodic pressure variations introduced by drilling fluid circulating equipment must be removed from the pressure signal so that the minute pressure changes at the onset of a well kick will not be masked or obscured.

Referring now also to FIG. 2, the transducer housing 20 of FIG. 1 may include an input connector 48 adapted to be connected to the standpipe 14 of FIG. 1. The connector 48 may be provided with a conventional diaphragm 50 therewithin and a conduit 52 connected between the diaphragm 50 and the linear transducer 16, as illustrated. The conduit 52 may be filled with a fluid 53, such as oil having a thermal conductivity less than that of the drilling fluid, for transmitting the mud pressure sensed at the diaphragm 50 to the linear transducer 16. The linear transducer 16 may be provided with a diaphragm or other pressure sensing surface 54 on which strain gauge or other pressure sensing elements 55 may be mounted. In the illustrated embodiment, the pressure sensing elements are arranged in a Wheatstone bridge configuration. Such a transducer is commercially available.

To obtain improved accuracy and precision, the pressure transducer 16 may be designed primarily for linearity and accuracy without regard to temperature stability. The special temperature compensation is necessarily employed in the illustrated embodiment. Simi-

larly, amplifier 28 need not be specially designed to accommodate temperature variations.

Power for the pressure sensing elements 55 may be supplied from the power supply 26. Power from the power supply 26 may be applied to a reference potential regulating circuit 56 within the chamber 18 which provides a regulated voltage for the pressure transducer 16. The signal from the transducer 16 is applied to the amplifier 28 which amplifies the output signal to generate a differential output signal linearly related to the sensed pressure.

As described in connection with FIG. 1, the chamber 18 may be maintained at a constant high temperature above ambient by the electrical heating element 22 which derives power from the power supply 26 through the thermostat 24. The chamber 18 may be lined with insulating material 63 such that the chamber temperature and that of the components therein may be maintained substantially constant.

The output signal from the amplifier 28 is applied to the signal processing unit 30 which includes a second differential amplifier 58 whose output signal may be applied through a calibration adjustment circuit 59, a range or span control circuit 60, and a low pass filter circuit 62 having a variable damping adjustment. The calibration adjustment circuit 59 may include a conventional summing junction utilized to adjust the signal applied to the range control circuit 60 to a predetermined level in the absence of mud pressure. The range control circuit 60 may be in the form of a variable gain amplifier for setting the range or span of the pressure to utilize the scale of the indicators. Finally, the low pass filter 62 may be adjusted to have a damping function selected to remove short term periodic pressure variations due to drilling fluid circulating equipment, such as pump impulses, from the analog electrical signal before it is applied to the analog-to digital converter 32 (see FIG. 1). This may be accomplished by providing a differential amplifier with a slew rate sufficiently low in that short term periodic pressure fluctuations are not amplified. In this manner, an extremely accurate readout and indication of minute pressure changes may be obtained and the preconditions to a well blowout easily recognized.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. Apparatus for indicating down hole well pressure conditions in a wellbore containing pumping means for circulating a drilling fluid down into and up out of said wellbore comprising:

a housing having an interior chamber and adapted to be mounted adjacent a pipe carrying drilling fluid;

means for communicating the pressure of the drilling fluid within the pipe to the interior chamber of said housing;

means for maintaining the housing interior chamber at a constant temperature;

5

a linear pressure transducer located within the interior chamber and adapted to sense the pressure of said drilling fluid and to produce an electrical signal having an amplitude related to the drilling fluid pressure;

means within the housing interior chamber for linearly amplifying said electrical signal thereby to produce an amplified analog electrical signal;

means for producing a digital signal having at least three digits responsive to the amplitude of the analog electrical signal; and

means for displaying one or more of the least significant digits of the digital signal to provide a quickly readable indication of the direction and rate of drilling fluid pressure changes.

2. The apparatus of claim 1 including a low pass filter means connected between said amplifying means and said digital signal producing means for removing periodic amplitude variations from the analog electrical signal caused by pressure variations resulting from operation of the drilling fluid pumping equipment.

3. The apparatus of claim 2 wherein said displaying

6

means includes:

means for generating a first analog signal having an amplitude related to at least two of the most significant digits; and,

5 means for producing a time varying trace related in amplitude to that of the first analog signal.

4. The apparatus of claim 3 wherein said display

means includes:

10 means for generating a second analog signal having an amplitude related to at least two of the least significant digits; and,

means for producing a time varying trace related in amplitude to that of the second analog signal in juxtaposition to the trace of the least significant digit.

15 5. The apparatus of claim 4 wherein said means for producing a time varying trace includes a strip chart recorder having a pair of pens movable independently over the same chart in response to said first and second analog signals.

* * * * *

25

30

35

40

45

50

55

60

65