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METHOD OF DETECTING WASHOUTS IN ROTARY WELL DRILL STRINGS

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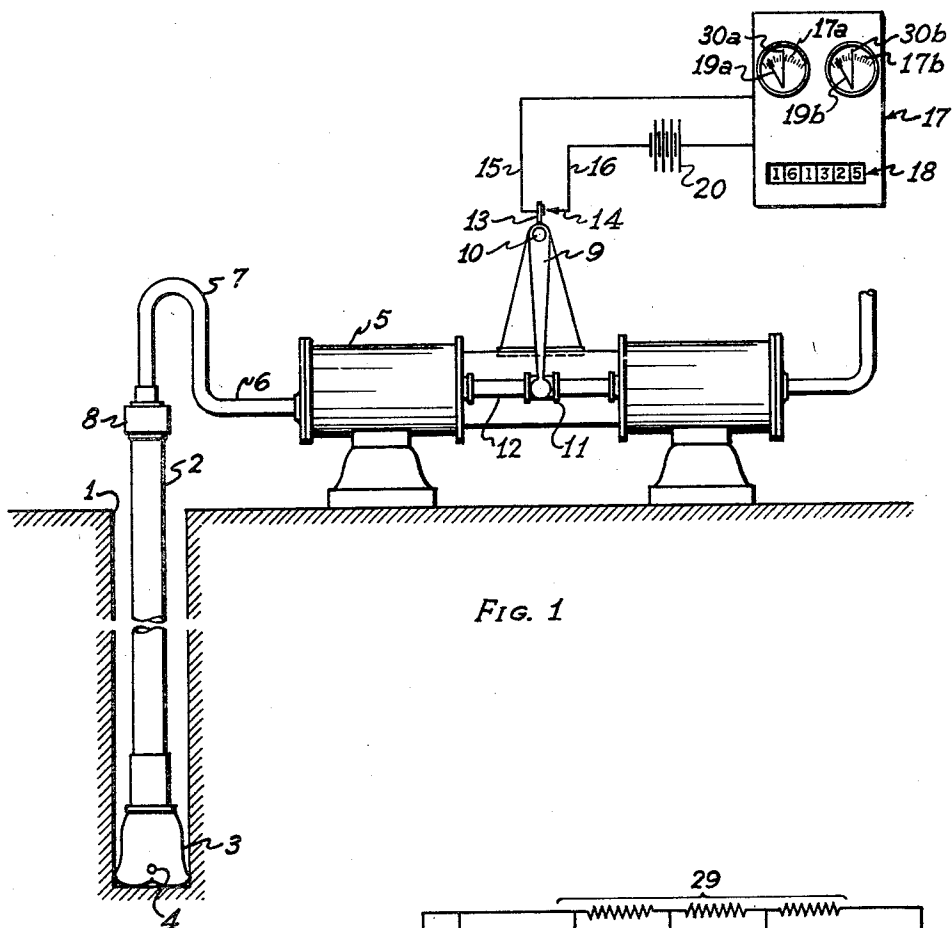


FIG. 1

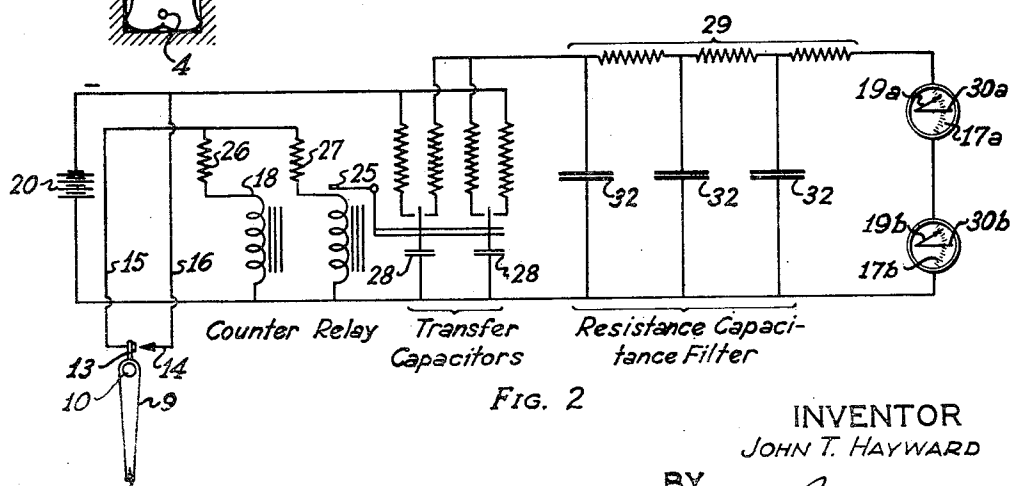


FIG. 2

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## UNITED STATES PATENT OFFICE

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METHOD OF DETECTING WASHOUTS IN  
ROTARY WELL DRILL STRINGS

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Original application March 4, 1939, Serial No.  
259,849. Divided and this application October  
2, 1939, Serial No. 297,475

10 Claims. (Cl. 255—24)

This application is a division of my co-pending application Serial No. 259,849, filed March 4, 1939. This invention relates to a method and apparatus for measuring the rate of flow of drilling fluids through a well during the drilling thereof, and for detecting and measuring the change in rate of flow of such drilling fluids.

In the ordinary course of drilling a well, such as an oil or gas well, by the rotary method, a hydraulic fluid, such as a mud fluid consisting ordinarily of a suspension of clay or earthy solids in water, is forced down through a string of hollow drill pipe to the bottom of the well, where it is discharged from the drill pipe through two holes in the bit, commonly known as the "eyes," thence upwardly through the annular space between the drill pipe and the wall of the well bore to the surface of the ground.

Accurate and continuous knowledge of the volume and rate of flow of the stream of mud fluid through the well is of great importance to the driller in many operations and is particularly important in connection with a continuous coring or logging method such as described in detail in my former application, Patent 2,214,674 of Sept. 10, 1940. Another important application is in the detection of "wash-outs" in the drill pipe.

Heretofore, no satisfactory method or apparatus has been devised for accurately and continuously measuring the volume and rate of flow of a mud fluid through a well. Because of the unusual and varying characteristics of such fluids, which are very abrasive in character, and vary very widely in their viscosity and densities during the drilling operation, all meters which have attempted to be applied to metering of such fluids have been rendered totally inaccurate and undependable in their measurements and none have been designed, as yet, which would accurately and continuously meter the volume or rate of flow of such drilling fluids through a well.

The present invention provides a new and successful method and apparatus which is particularly applicable for measuring the volume and rate of flow of mud fluids through a well during the drilling thereof, and in addition, simultaneously provides a novel and highly successful method and apparatus for detecting impending "wash-outs" in the drill pipe by detecting the change in rate of flow of the drilling fluid through the well.

The present application is a division of my application 259,849 filed March 4, 1939.

With reference to "wash-outs," it should be

noted that the so-called "eyes" of a drilling bit are ordinarily about three-quarters or seven-eighths of an inch in diameter and because of their relatively restricted openings and the friction in the drill pipe, considerable pressure, generally in excess of 100 pounds per thousand feet of drill pipe, is required to cause the mud fluid to circulate through the well. Since strings of drill pipe up to 10,000 feet or more in length are employed in many cases of well drilling, pressures of several hundred pounds to well above one thousand pounds may be required. Under such high pressures, should a crack or pin hole be present or develop in the wall of the drill pipe, or should there be a slight leak in any of the threaded connections between the sections of drill pipe, the mud fluid will be forced through such defective spots and by its abrasive action under the high pressure, will very rapidly enlarge the opening until so much of the pipe metal is eroded away that the pipe is severed or parts of its own weight at the point of erosion. This condition is commonly referred to as a "wash-out" and results in the loss of the lower portion of the drilling string in the well requiring a so-called "fishing-job" to recover this portion from the well. Fishing jobs are expensive, time-consuming, and in extreme cases may even cause loss of the well or at least may require that the well be "side-tracked" past the unrecovered pipe and redrilled for a substantial portion of its depth. About ninety percent of all fishing jobs in rotary drilling are the result of wash-outs, and it will be evident, therefore, that any method which will warn against such wash-outs before they have progressed to the point of disruption of the drilling pipe will be of great value to the industry.

It will be obvious that, as compared with two three-quarters or seven-eighths inch holes at the bottom of the string of drill pipe, any small opening in some upper portion of the drill pipe will cause an increase in the rate of mud circulation. It has been discovered that a wash-out is always preceded by a steady but slow increase in the flow rate—usually extending over two to four hours before the pipe fails. The pumps commonly used on rotary rigs for circulating the mud fluid are ordinarily direct-acting pumps and are more-or-less constant pressure devices which tend to maintain the discharge pressure by speeding-up whenever the total resistance against their delivery is decreased. It has been found, therefore, that by providing suitable means for quickly detecting increases in the rate of such pumps, impending wash-outs may be readily de-

tected at their inception, and the drilling thereupon stopped and the defective pipe withdrawn before the complete failure of the drill pipe with its attendant fishing job occurs. At the same time the novel apparatus employed for detecting wash-outs also functions very efficiently for measuring continuously the rate and volume of flow of the mud fluid through a drilling well, as will be described more fully hereinafter.

As ordinarily connected in a rotary rig, the mud circulation pumps are out of sight of the driller, and in any case, the rate of increase of their speeds is generally so slow before a complete wash-out occurs, that it will ordinarily escape the attention even of an observer stationed at the pumps.

It is, therefore, a principal object of this invention to provide a novel method for measuring the rate and volume of flow of mud fluid through a well.

Another important object is to provide a novel method for detecting incipient wash-outs in drill pipe by observing the change in the rate of flow of mud fluid through a drilling well.

A more specific object is to provide a method for detecting wash-outs of drill pipe by measuring the speed rate at which a constant pressure pump circulates mud fluid through a drill pipe, and detecting and measuring the change in rate of the pump.

Another object is to provide an apparatus suitable for detecting changes in rate of operation of pumps employed in circulating drilling fluids through wells, whereby the rate and volume of flow of mud fluid through a well may be measured and incipient wash-outs quickly detected.

Other and more specific objects of this invention will become apparent from the following description taken in conjunction with the accompanying drawing which illustrates a form of apparatus particularly adapted for successfully accomplishing the aforementioned and other objects of this invention.

In the drawing:

Fig. 1 illustrates an arrangement suitable for accomplishing the purposes and objects of this invention.

Fig. 2 is a schematic drawing of electrical apparatus used in connection with the apparatus of Fig. 1.

Referring to the drawing, Fig. 1 shows a well 1 in which is inserted a string of hollow drill pipe 2 such as is ordinarily employed in rotary drilling for turning a bit 3 connected to the lower end thereof and provided with conventional openings or eyes 4. A pump 5 has its discharge pipe 6 connected to the usual rotary hose 7, which is attached by means of a swivel 8 to the upper end of drill pipe 2. Pump 5 is of the well-known direct-acting type which operates at more-or-less constant pressure which is maintained against reduced resistance in the stream of fluid being pumped by the speeding-up of the pump. The pump is conveniently driven by steam which is usually supplied at a constant pressure and at a volume sufficient to maintain a constant discharge pressure on the pump. While pump 5 is illustrated as a simplex, or single cylinder pump, it may be and usually is a duplex type pump. Pump 5 has the usual rocker arm 9, which is suitably connected at its upper end to oscillate about a bearing 10 and has its lower end rotatively seated in the usual cross head 11, which is fixedly mounted on the

piston rod 12 in the usual manner. The rest of the pump valve gear conventionally attached to and operated by pump rocker arms, such as rocker arm 9, is not shown. Attached to the upper end of rocker arm 9 is a fixed switch terminal 13 which oscillates with the movement of the rocker arm and, during a portion of the oscillatory arc, makes contact with a switch point 14. Switch terminal 13 and switch point 14 are so positioned relative to each other that they make contact with each other during a portion of each cycle of the pump piston. Switch terminal 13 and switch point 14 are connected by wire leads 15 and 16, respectively, to an electrical rate meter, indicated generally at 17, and to an electrical cycle counter, indicated at 18, both of which will be described in greater detail hereinafter. A suitable source of direct current, such as a battery 20, is connected into the circuit in lead 16. The switch which includes switch terminal 13 and switch point 14 may be of any suitable design which is adapted to open and close during each cycle of pump 5 so as to permit recording of the pump cycles by rate meter 17 and counter 18.

Fig. 2 shows the schematic arrangement of the electrical circuit employed in connection with rate meter 17 and cycle counter 18. Starting at the left hand end of the diagram, we find a battery 20, for which any suitable source of constant direct current voltage may be substituted. Lead 16 from switch point 14 next connects into the circuit and lead 15 from switch terminal 13 is connected to electrical counter 18, which is of conventional design and adapted to count the total number of cycles made up by pump 5, and to a slow-acting relay 25 through respective resistors 26 and 27. Relay 25 operates a pair of transfer capacitors 28—28 which discharge into a measuring circuit which comprises a three-section resistance-capacitance filter 29, each section of which is provided with its respective condenser 32, and which is in turn connected to a micro-ammeter, which is preferably provided with two scales 17a and 17b. Scale 17a is calibrated in stroke cycles per minute to function as the cycle rate meter for pump 5 and scale 17b in barrels per minute, the latter being directly derived from the former by multiplication thereof by a constant determined from the volumetric capacity of the pump in barrels per cycle. Scale 17b will, therefore, give direct readings in barrels per minute. Instead of a single meter having two scales, two separate meters, as shown, may be used. Each of the scales is provided with a rate indicator hand 19a and 19b, respectively, and one or both with normal index pointers 30a and 30b, respectively, which are adapted to be set manually at any desired point along the respective scales 17a and 17b relative to a predetermined normal operating position of the indicator hands 19a and 19b.

This circuit operates as follows: Each time the pump 5 operates through a cycle, the switch operated by rocker arm 9 is open and closed. The corresponding operation of relay 25 causes one of the transfer capacitors 28 to close on the side toward the voltage source and to be charged fully to the voltage of the circuit. It is then moved to the other side of the relay contact and discharged into measuring circuit 29 down to the voltage on the first filter condenser 32. During this time the other transfer capacitor 28 is acting similarly, except that its timing is reversed, and it charges while the first one

is discharging, then discharges while the first one is charging again. It can be seen that the reading of the meter, or meters if two are used, will be directly proportional to the voltage supplied from source 20 and will also be somewhat proportional to the capacitance of the transfer capacitors.

The measuring circuit 29, as indicated, constitutes a filter arrangement to smooth out the pulses of current so as to give a steady reading on the meters rather than a reading varying through wide limits after each condenser discharge. It is found to be not practical to use a single section filter for two reasons. In the first place, the time required for the meters to arrive at steady state readings was excessive, being of the order of several minutes, and secondly, the remaining amplitude of current pulses was also excessive for any reasonable amount of capacitance and resistance used in the filter. It was found practical to use a three-section filter and thereby attain a satisfactory smoothness of the reading and also a satisfactory quickness of response in attaining a steady state reading.

The apparatus hereinabove described is employed as follows: Cycle rate meter 17 is positioned on the drilling rig under the immediate observation of the driller, usually, whose position in ordinary drilling practice is remote from the pumps 5. With pump 5 operating at a normal speed to circulate mud fluid through the well 1 at the required rate, the normal indicator hands 19a and 19b will reach steady states at some definite positions on scales 17a and 17b, respectively, corresponding to the normal rate of operation of the pump, as long as no leaks occur in the drill pipe 2. The normal index pointer 30a is then set in advance of this position on scale 17a, for example, at a position marking a 20% increase in the normal speed of the pump. Then, when any leak occurs in the drill pipe 2, the pump rate will immediately show an increase corresponding to the rate of leakage of fluid from the drill pipe and the indicator hand 19a will move toward the position of the normal index pointer 30a, and will thus immediately indicate to the driller that an incipient wash-out is in progress, and being thus warned, he can immediately halt the drilling operation and withdraw the drill pipe for replacement of the pipe section or sections which are found to be defective. The index pointer 30b may be set, similarly, in advance of the normal reading of indicator 19b on scale 17b, and will, of course, function in a similar manner to show change in volume rate of the pump.

Counter 18 will total the number of cycles made by pump 5, and from the number of strokes or cycles it records in any given period of time the total volume of fluid circulated in that period of time may be readily calculated by multiplying that number by the volume per cycle factor for the pump.

Thus it will be evident that this invention discloses a novel method and apparatus for metering the volume and rate of flow of the drilling fluid during the drilling of a well, and for warning against incipient wash-outs of the drill pipe, the method comprising forcing drilling fluid through the drill pipe and the well in a pulsating stream of predetermined volume per pulsation, and counting the number of pulsations to measure the volume of fluid circulated through the well, measuring the number of pulsations per unit of time to determine the rate of circulation, and observing the changes in rate of pulsation

under constant pressure to thereby detect incipient or impending wash-outs.

Instead of the described electrical cycle rate meter 17, and electrical counter 18, various forms of mechanical, hydraulic or pneumatic devices may be substituted for operation directly or indirectly by the movement of the rocker arm 9 of pump 5.

What I claim and desire to secure by Letters

Patent is:

1. In the method of drilling wells wherein a hydraulic fluid is circulated into and out of a well through a hollow drill pipe by a pump of fixed volumetric capacity per stroke cycle, the method of detecting incipient wash-outs in said drill pipe which comprises, forcing a stream of said hydraulic fluid through said drill pipe and said well at a predetermined normal pulsation rate of said pump, and observing increases in said normal pulsation rate by observing the gradual increases in the stroke cycle rate of said pump while maintaining substantially constant pressure on said stream of fluid to thereby detect incipient wash-outs.

2. In the method of drilling wells wherein a hydraulic fluid is circulated into and out of a well through a hollow drill pipe by a pump of fixed volumetric capacity per stroke cycle, the method of detecting incipient wash-outs in said drill pipe which comprises, forcing a stream of said hydraulic fluid through said drill pipe and said well by said pump, measuring the stroke rate of said pump and establishing thereby a predetermined normal stroke rate for said pump, continuing the measurement of the stroke rate of said pump throughout the drilling operation while maintaining a substantially constant pressure on said stream of fluid, and observing gradual progressive increase in said normal stroke rate of said pump during said drilling operation to thereby detect incipient wash-outs in said drill pipe.

3. In the method of drilling wells wherein a hydraulic fluid is circulated into and out of a well through a hollow drill pipe by a pump of fixed volumetric capacity per stroke cycle, the method of detecting incipient wash-outs in said drill pipe which comprises, forcing a stream of said hydraulic fluid through said drill pipe and said well by said pump, measuring the stroke rate of said pump and establishing thereby a predetermined normal stroke rate for said pump, continuing the measurement of the stroke rate of said pump throughout the drilling operation while maintaining substantially constant pressure on said stream of fluid and continuously comparing the stroke rate of said pump during the drilling operation with said normal stroke rate to thereby detect during the drilling operation increases in said stroke rate which are indications of the incipient wash-outs in said drill pipe.

4. In the method of drilling wells wherein a hydraulic fluid is circulated into and out of a well through a hollow drill pipe by a pump of fixed volumetric capacity per stroke cycle, the method of detecting incipient wash outs in said drill pipe developing over extended periods of time during drilling which comprises, forcing a stream of said hydraulic fluid through said drill pipe and said well at a predetermined normal cycle rate by said pump, providing a fixed visual indication of said normal cycle rate, continuously measuring the cycle rate of said pump throughout the drilling operation while maintaining substantially constant pressure on said stream of fluid, and providing a continuous visual indication

thereof, whereby the latter may be continuously and directly compared with said fixed visual indication to thereby permit continuous detection of gradual increases in said normal cycle rate of said pump.

5. A method according to claim 2 wherein the mechanical stroke movements of said pump are converted into electrical quantities, and the resulting electrical quantities measured to provide the therein mentioned rate measurements.

6. In the drilling of wells wherein a hydraulic fluid is circulated into and out of a well through a hollow drill pipe, the method of detecting incipient wash-outs in said drill pipe which comprises, forcing said fluid through said drill pipe and said well in a pulsating stream, establishing a predetermined normal pulsation rate therefor, continuously measuring the pulsation rate during the drilling while maintaining substantially constant pressure on said stream, and continuously comparing the measured pulsation rate with said normal pulsation rate to thereby obtain an indication of gradual increases in said normal rate which are indicative of incipient wash-outs.

7. In the drilling of wells wherein a hydraulic fluid is circulated into and out of a well through a hollow drill pipe, the method of detecting incipient wash-outs in said drill pipe which comprises, forcing a stream of drilling fluid through said pipe and said well at a predetermined normal rate of flow, continuously maintaining constant pressure on said stream entering said drill pipe, providing an indication of said normal rate, producing a continuous indication of the rate of said fluid while said constant pressure is maintained on said stream, and continuously comparing said continuous indication with said indication of said normal rate to thereby detect gradual increases in said normal rate whereby to detect incipient wash-outs in said drill pipe.

8. In the drilling of wells wherein a hydraulic fluid is circulated into and out of a well through a hollow drill pipe, the method of detecting incipient wash-outs in said drill pipe which comprises, forcing drilling fluid through said drill pipe and said well in a pulsating stream at a predetermined normal pulsation rate, maintaining constant pressure on said stream entering the drill pipe, providing an indication of said normal pulsation rate, producing a continuous indication of pulsation rate throughout the drilling operation while said constant pressure is maintained on said stream, and continuously comparing said continuous indication with said indication of said normal rate to thereby detect increases in said normal rate whereby to detect incipient wash-outs in said drill pipe.

9. In the art of drilling deep wells by the rotary method in which a fluid is circulated under a normally maintained pressure down a rotating drill stem and upwardly outside thereof, the process of detecting incipient leaks at various points along the drill stem during the regular course of drilling, comprising forcing the fluid down the drill stem, causing a variation in the rate of flow of the fluid attendant upon such an incipient leak, and indicating such variation.

10. In the art of drilling deep wells by the rotary method in which a fluid is circulated under a normally maintained pressure down a rotating drill stem and upwardly outside thereof, the process of detecting incipient leaks at various points along the drill stem during the regular course of drilling, comprising, forcing a normally pulsating stream of the fluid down the drill stem, causing an abnormal variation in the pulsation rate of the fluid attendant upon such an incipient leak, and indicating such abnormal variation.

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