May 8, 1951 J. W. PITCHER ET AL 2,552,454

APPARATUS FOR MEASURING THE RATE OF DRILLING FLUID FLOW THROUGH WELLS

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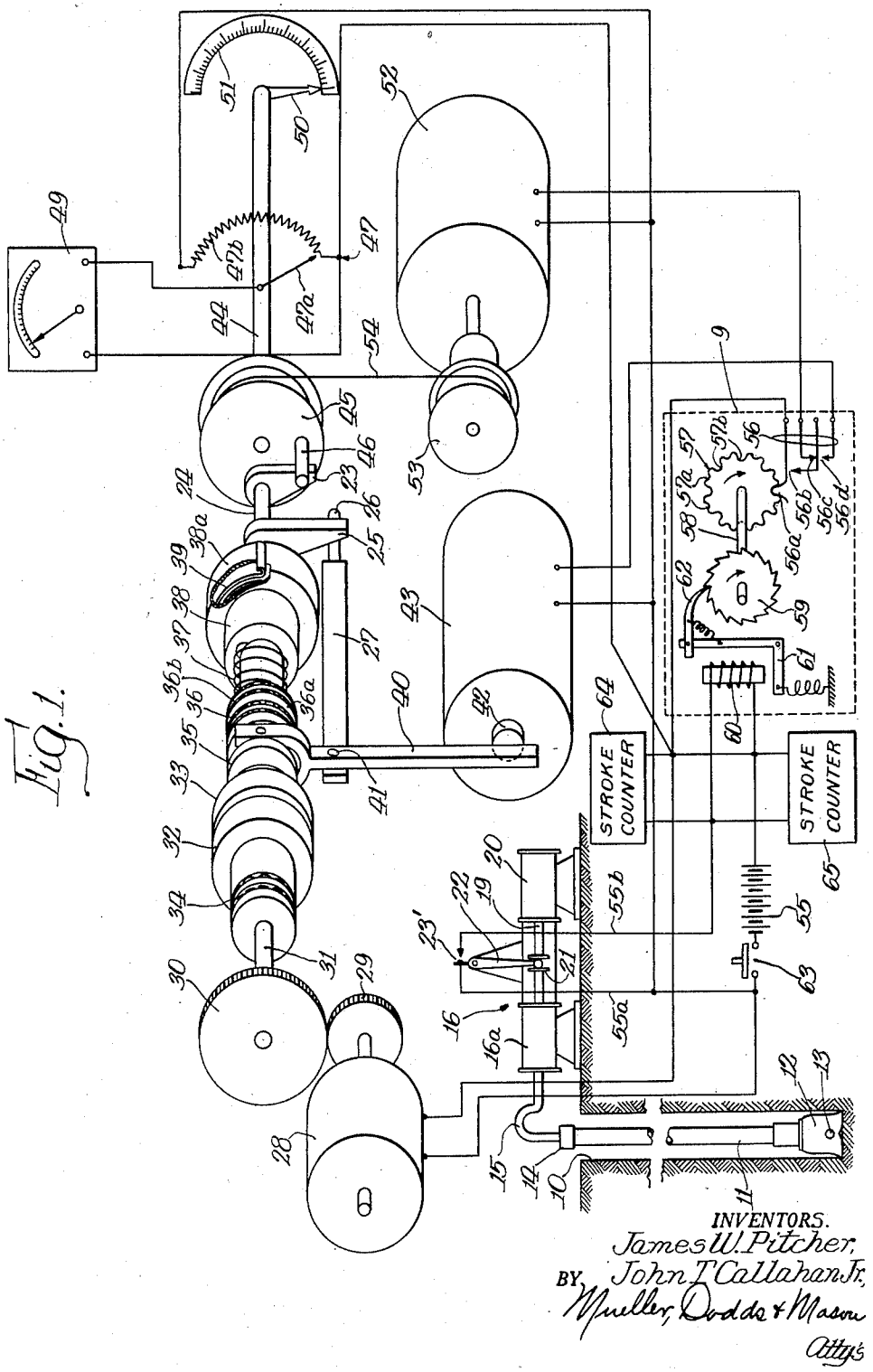


Fig. 1.

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Fig. 3.

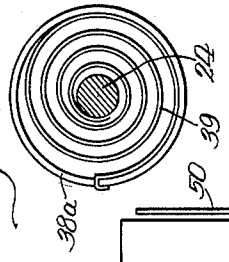


Fig. 2.

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APPARATUS FOR MEASURING THE RATE OF DRILLING FLUID FLOW THROUGH A WELL

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1 Claim. (Cl. 73—194)

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The present invention relates to improved apparatus for measuring the rate of flow of a drilling fluid through a well during a well drilling operation and for indicating changes in the rate of flow of a drilling fluid into a well.

In conventional well drilling operations, such, for example, as in the drilling of oil or gas wells by the rotary method, a drilling fluid or mud consisting usually 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 for return flow upwardly through the annular space between the drill pipe and the wall of the well bore to the surface of the ground or in reverse order. As pointed out in Hayward Patent No. 2,290,179 granted July 21, 1942, accurate and continuous knowledge of the volume and rate of flow of the drilling fluid through the well is of great importance to the driller and is particularly important in connection with continuous coring or logging. It is also important in the detection of what is known as "wash outs" in the drill pipe, which if permitted to proceed without detection, result in parting of the drill pipe with the resultant necessity for a "fishing" operation. Various methods and apparatus have been employed for obtaining an indication of the rate of drilling fluid flow for the purposes specified. In general, prior art apparatus of this character is rather delicate, and hence is not well suited to the rough handling ordinarily encountered in use. The prior art devices are also rather expensive to manufacture and service, since the services of a skilled technician are required in the calibration and repair thereof.

It is an object of the present invention, therefore, to provide improved apparatus for indicating the rate of drilling fluid flow through a well during a well drilling operation.

It is another object of the invention to provide apparatus of the character described which is of rugged and economical construction, may be easily installed, operated and serviced by relatively unskilled users of the apparatus, and is reliably accurate in its operation to provide an indication of the rate of drilling fluid flow into a well and any changes in the rate of flow.

The invention both as to its organization and method of operation, together with further objects and advantages thereof will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which:

Fig. 1 is a schematic view illustrating improved

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apparatus characterized by the features of the present invention;

Fig. 2 is a side mechanical view illustrating one structural embodiment of the apparatus; and

Fig. 3 is a detail view illustrating certain components of the apparatus.

Referring now to the drawings, and more particularly to Fig. 1 thereof, the present improved apparatus is illustrated in its use to measure the rate of drilling fluid flow through a well 10 in which is inserted a string of hollow drill pipe 11 of the character ordinarily employed in a rotary drilling operation to rotate a drill bit 12 connected to the lower end of the drill pipe string and provided with drilling fluid openings 13. Drilling fluid or mud of the type ordinarily used in a drilling operation is delivered to the drill pipe 11 internally thereof and under pressure by means of a pump 16 having its discharge end connected to the upper end of the drill pipe string 11 through the usual rotary hose 15 and swivel 14. The pump 16 is of the well-known direct acting type and is designed to operate at a substantially constant pressure which is maintained against changing resistance in the stream of drilling fluid being pumped into the drill pipe string 11 by a change in the speed of the pump. The pumping piston within the cylinder 16a is conventionally driven by a steam piston and cylinder assembly 20 through a piston rod 19, the usual rocker arm 22 being provided to control the steam entrance and exit valves of the pumping cylinder. This arm is pivotally supported adjacent its upper end and has its lower end connected to the usual cross head 21 which reciprocates with the piston rod 19. Thus, during reciprocation of the pump 19, back and forth pivotal movement is imparted to the rocker arm 22. This motion of the arm 22 is utilized to open and close a set of control contacts 23', the arrangement being such that these contacts are closed during each pumping stroke of the pump and are opened during each intake stroke of the pump. The current pulses produced through opening and closing of the contacts 23', are thus generated at a rate which varies in accordance with variations in the pumping rate and hence in the rate of drilling fluid delivery to the well and are utilized to control the present improved measuring apparatus.

In brief, this apparatus comprises an actuating or indicating element 23 in the form of an arm carried by a rotatable shaft 24 and having a normal or reference setting which is determined

by engagement of a stop arm 25, also fixedly carried by the shaft 24, with a stop 26 fixedly mounted upon the upstanding frame member 34a of the apparatus. For the purpose of measuring the time required for the completion of certain pumping strokes of the pump 16, driving means including a constant and slow speed motor 28 are provided for moving the element 23 away from its normal setting. More specifically, the motor 28 is normally connected in driving relationship with the element 23 through a driving connection which comprises a gear train 29, 30, a shaft 31, and a pair of engaged clutch members 32 and 33, the first of which is mounted for rotation with the shaft 31, and the second of which is mounted for rotation with the shaft 24. The shaft 24 is journalled for rotary and axial movement in a bearing member 38 which is carried by the frame member 34a. This bearing member is provided with an enlarged cup-shaped part 38a which houses a helical restoring spring 39 having the function of normally biasing the shaft 24 and the element 23 to their respective normal settings, i. e., to positions wherein the stop arm 25 engages the stop 26. The motor 28, gear train 29, 30, shaft 31 and clutch member 32 are supported upon a second upstanding frame member 34b, suitable bearing means being provided upon this frame member for receiving the shaft 31. For the purpose of normally maintaining the two clutch members 32 and 33 in clutching engagement, a compression spring 37 is provided which is held under compression between the end of the bearing member 38 and the clutch member 33. To provide for intermittent declutching of the two clutch members, a clutch release mechanism is provided which comprises an element 35 mounted by the shaft 24 and movable axially and rotatably relative thereto. This element is interposed between the clutch member 33 and a thrust member 36a keyed to the shaft 24 and against which the spring 37 directly bears. A ball bearing assembly 36 is interposed between the element 35 and the thrust sleeve 36a, and a second ball bearing assembly 34 is provided between the clutch member 32 and the bearing for the shaft 31, these two bearing assemblies coacting to absorb the thrust of the spring 37 when the two clutch members are engaged, and thus provide for unrestricted rotation of the two shafts 24 and 31 under the influence of the motor 28. Similarly, a ball bearing assembly 36b is interposed between the thrust member 36a and the left end of the spring 37 to coact with the ball bearing assembly 36 in permitting free rotation of the shaft 24 under the influence of the retracting spring 39 when the two clutch members are disengaged.

Declutching of the two clutch members 32 and 33 is effected through operation of an electromagnet 43 having a plunger 42 which is adapted to thrust against the lower end of an arm 40 pivotally mounted by means of a pivot pin 41 upon a supporting member 27 which is carried by and projects laterally from the upstanding frame member 34a of the device. At its opposite end, this arm is bifurcated to embrace the element 35, and the bifurcations carry opposed fingers entering the channel of this element to provide the required mechanical connection between the parts 35 and 40. As explained below, the solenoid 43 is arranged for intermittent energization under the control of the contacts 23' at the rate of one energizing pulse for each alternate stroke of the pump 16.

For the purpose of indicating the off-normal settings which are imparted to the element 23 through operation of the above-described facilities, indicating means are provided which comprise a rotatable shaft 44 having mounted for rotation therewith an indicating pointer 50 which is cooperable with a scale 51 to identify the angular setting thereof. If electrical means are to be employed in indicating the rate of drilling fluid flow as represented by the angular setting of the shaft 44, this shaft may also be utilized to control the setting of an adjustable potentiometer 47 mounted upon the frame member 34c and having a wiper arm 47a rotatable with the shaft 44 in sliding engagement with a resistor element 47b. This potentiometer may be used to control the indication of a measuring instrument 49 having its scale appropriately graduated in terms of drilling fluid flow. A one-way lost-motion driving connection is provided between the shaft 44 and the element 23 for the purpose of causing this shaft to follow movement of the element 23 away from its normal setting. This connection comprises a reel or drum 45 fixedly connected to the shaft 44 adjacent the element 23 and provided with an eccentrically mounted pin 46 which is engageable with the element 23.

In order to rotate the shaft 44 in the reverse direction when the increments of movement of the element 23 away from its normal setting are decreased, reverse driving means are provided which comprise a torque motor 52 supported by the frame member 34c. This motor is arranged for intermittent energization under the control of the pump 16 and is provided with a pulley 53 fixedly connected to its rotor shaft and connected by means of a string 54 to the pulley 45. One or two turns of this string are wrapped around each pulley and the respective ends thereof are fixedly attached to the two pulleys.

In order to energize the motor 52 and the magnet 43 during alternate strokes of the pump 16, and in accordance with variations in the rate of operation of this pump, a control device 9 of the magnet operated, ratchet and pawl type is provided. Specifically, this device comprises a contact spring assembly 56, the inner spring 56a of which is arranged for actuation by an eight point star wheel 57 mounted for rotation with a shaft 58 which also carries a sixteen tooth ratchet wheel 59. This ratchet wheel is arranged for actuation by a spring biased pawl 62 carried by a spring biased armature 61 in response to energization of the operating magnet 60. The structural arrangement of the device is such that during the delivery of alternate current pulses to the magnet 60, the contact springs making up the assembly 56 are actuated to their respective off-normal positions, and are returned to their respective normal settings during the delivery of each intervening pulse to the operating magnet 60.

For the purpose of directly counting and registering the strokes of the pump 16, a pair of electro-magnetically operated counting devices 64 and 65 of any desired type are provided. Current for energizing the operating magnets of the two identified counters, the magnet 60 of the control device 9, the release magnet 43, the timing motor 28 and the torque motor 52, is supplied by a current source 55 of appropriate voltage through a master switch 63. If desired, this switch may be suitably interlocked with the steam admission valve of the pump 16 so that

when operation of the pump is initiated, the described apparatus for measuring the rate of drilling fluid flow will also start to operate.

In using the described apparatus in the field, the only operations required in setting up the apparatus for use are those of connecting an available current source 55 of appropriate voltage into the circuit and appropriately connecting the conductors 55*a* and 55*b* to the contacts 23' controlled by the mud pump 16. When operation of the pump 16 to deliver drilling fluid to the well 10 is started, the switch 63 is also closed to initiate operation of the motor 28 and activate the remaining parts of the circuit. With the motor 28 in operation, the element 23 is driven away from its normal setting through the driving connection afforded by the gear train 29, 30, the shafts 31 and 24, and the engaged clutch members 32 and 33. Since the motor 28 is a constant speed device, movement of the element 23 away from its normal setting proceeds at a constant rate of speed. As the element 23 is rotated away from its normal setting, it correspondingly rotates the shaft 44 through the driving connection afforded by the pulley 45 and the pin 46. In other words, the shaft 44 and the indicating elements carried thereby follow the movement of the element 23 away from its normal setting. Such rotation of the shaft 44 and the pulley 45 also results in rotation of the torque motor rotor through the connection provided by the string 54.

With the pump 16 in operation, the rocker arm 22 functions intermittently to close the contacts 23'. Each time these contacts are closed to indicate a stroke of the pump 16, a current pulse is delivered to each of the two stroke counters 64 and 65 in an obvious manner, and also to the operating magnet 60 of the control device 9. When thus energized, the magnet 60 attracts its armature 61 to advance the star wheel 57 one step through the driving connection provided by the shaft 58, the ratchet wheel 59, and the pawl 62. Assuming that the parts of the control device 9 occupy their illustrated positions when any given pulse is delivered to the magnet 60, the star wheel 57 is advanced one step to bring a high point 57*a* beneath the contact spring 56*a*, thus moving this spring to first close the contacts 56*b*, then open the contacts 56c and thereafter close the contacts 56*d*. Incident to the momentary closure of the contacts 56*b* a circuit is completed through these contacts and the contacts 56c for energizing the torque motor 52.

During the initial operation of the apparatus such energization of the motor 52 is without effect since the pin 46 is directly engaged with the element 23. Immediately the contacts 56c are opened, the torque motor 52 is deenergized. When thereafter the contacts 56*d* are closed, a circuit is completed through these contacts and the contacts 56*b* for energizing the magnet 43. In operating, this magnet attracts its plunger 42 into engagement with the lower end of the arm 40, thereby to move the declutching element 35, the shaft 24 and the clutch member 33 slightly to the right and thus disengage the clutch member 33 from the clutch member 32. When thus released from the driving force of the motor 28, the shaft 24 and the parts carried thereby are returned to normal under the influence of the spring 39, which spring is obviously tensioned during movement of the element 23 away from its normal setting. Thus, the element 23 is restored to normal and the shaft 44 is left standing in the position to which it was actuated during

movement of the element 23 away from its normal setting.

During the next succeeding pump stroke when the magnet 60 is again energized, the star wheel 57 is advanced a second step to bring a low point 57*b* thereof into engagement with the contact spring 56*a* and thus permit opening of the contacts 56*b* and 56*d* and reclosure of the contacts 56c. In this regard it will be noted that when the contacts 56*b* are opened, the magnet 43 is deenergized to permit reengagement of the clutch members 32 and 33 under the influence of the spring 37. It is also noted that the contact springs of the assembly 56 are so arranged that during the described normalizing thereof the contacts 56*b* are opened before the contacts 56c are reclosed, thereby to prevent spurious current pulses from being delivered to the motor 52.

Incident to re-engagement of the clutch members 33 and 32, the motor 28 is again rendered operative to drive the element 23 away from its normal setting. The increment of movement which occurs during the interval between pump strokes is, of course, determined by the rate of operation of the pump 16. If this rate of operation is decreasing, the interval between the last described pulse delivery to the magnet 60 and the next succeeding pulse will, of course, be of increased length, so that the element 23 will be moved a greater increment away from its normal setting during the pump stroke timing interval under consideration than the increment of movement which occurred during the preceding pump stroke timing interval. In moving beyond its previous off-normal setting, the element 23 further advances the shaft 44 and the indicating elements 50 and 47*a* carried thereby away from their respective normal settings. Hence during the next succeeding current pulse interval, in response to which current is again delivered to the torque motor 52 and the release magnet 43 in the order named, the torque motor is still ineffective to rotate the shaft 44 back toward its normal setting. Energization of the release magnet 43 results in normalizing of the element 23 in the exact manner explained above.

From the preceding explanation, it will be understood that so long as the rate of operation of the pump 16 decreases to indicate a decrease of the rate of drilling fluid delivery to the well 10, the increments of movement of the element 23 away from its normal setting which occur during alternate strokes of the pump 16 are progressively increased to progressively move the shaft 44 and the indicating elements controlled thereby farther away from their respective normal settings. When the pump 16 settles down to a constant rate of operation, representing a constant rate of drilling fluid flow into the well 10, the increments of movement of the element 23 away from the normal setting of this element become constant. In this case also, the momentary energization of the torque motor 52 which occurs at the end of each pump stroke timing interval is likewise without effect to produce movement of the shaft 44. Thus, the indicating elements are held in settings representative of the constant rate of drilling fluid flow into the well 10.

When, on the other hand, the rate of operation of the pump 16 increases to indicate that the rate of drilling fluid flow into the well is increasing, the periods separating the current pulses delivered to the magnet 16 become correspondingly shorter. As a result, the increments of movement of the element 23 away from

its normal setting which occur during alternate strokes of the pump 16 are correspondingly decreased, so that in each instance the element 23 stops short of engagement with the pin 46. In such case the momentary energization of the torque motor 52 which occurs at the end of each pump stroke timing interval results in rotation of the shaft 44 a small increment back toward it normal setting by the driving force exerted thereon through the pulley 53, the string 54 and the pulley 45. In this regard it is noted that regardless of the setting of the element 23 relative to the pin 46 at the time the torque motor 52 is energized, this motor is only capable of developing sufficient torque during its momentary energization to move the shaft 44 a small increment back toward its normal setting. Thus, it will be understood that if a large increase in the speed of operation of the pump 16 occurs and is sustained, several pump cycles will elapse before the torque motor 52 fully returns the shaft 44 to a setting representative of the actual pump speed, i. e. a setting wherein the pin 46 is engaged with the element 23. The purpose of this arrangement is to prevent the shaft 44 and the indicating elements carried thereby from following transient increases in the rate of operation of the pump 16 which may not be truly representative of a sustained increase in the rate of drilling fluid flow into the well 10.

From the above explanation, it will be apparent that the shaft 44 is controlled rapidly to follow any decrease in the rate of operation of the pump 16 but only slowly to follow an increase in the rate of operation of this pump. It will also be understood that the indicating element 50 assumes a setting relative to the scale 51 which is indicative of the rate of pump operation and hence of drilling fluid flow into the well. Preferably this scale is suitably graduated to indicate the drilling fluid flow directly. Similarly, the wiper arm 47*a* is variably positioned along the resistor 47*b* in accordance with the rate of drilling fluid flow into the well 10. This wiper, when adjustably positioned along the resistor 47*b*, impresses a variable portion of the voltage of the source 55 across the terminals of the indicating instrument 49, this voltage increment increasing with a decrease in the rate of drilling fluid flow and vice versa. Thus by suitable graduation of the instrument scale, the instrument 49 may be controlled directly to indicate the rate of drilling fluid flow into the well 10.

As indicated above, the counters 64 and 65 are provided for directly counting the strokes of the pump 16. Preferably the counter 64 is used to total the number of strokes made by the pump 16 during any given operating period of this pump. The counter 65 is used in conjunction with the counter 64 to indicate when a given increment of drilling fluid entering the well 10 through the drill pipe 11 will return to the surface of the well. To this end, and with the pump 16 in operation, cellophane chips may be introduced into the drilling fluid stream and the number of pump strokes actually required to return the chips to the surface counted by observation of the counter 64. For a given well depth this information may be used to set the counter 65. Thus, by advancing the setting of the counter 65 ahead of the setting of the counter 64 by the number of strokes required on the part of the pump 16 to circulate the chips through the well and then permitting the two counters to continue operating with the indicated difference between the settings thereof, the driller can at any time observe exactly when any given increment of drilling fluid entering the well will return to the surface. This information is important in conventional continuous well logging methods.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention as defined in the appended claim.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

Apparatus for determining the rate at which a pump delivers fluid to a well during a well drilling operation, comprising constant speed driving means, an element movable by said driving means away from a reference setting to an off-normal setting representative of the rate of fluid delivery into said well, a release magnet, means responsive to energization of said release magnet for returning said element to its reference setting, means responsive to operation of said pump for intermittently energizing said release magnet at a rate which varies in accordance with variations in the rate of operation of said pump, whereby variations in the increments of movement of said element away from said reference setting are produced in response to variations in said pumping rate, an indicating element directly actuated by said first-named element to indicate any increase in the increment of movement of said first-named element away from said normal setting, motor means for causing said indicating element to follow any decrease in the increments of movement of said first-named element away from said reference setting, and means responsive to operation of said pump for energizing and then deenergizing said motor means just prior to energization of said magnet.

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