Feb. 3, 1953 J. T. HAYWARD ET AL 2,627,178

LIQUID LEVEL RATE OF CHANGE INDICATING DEVICE

Filed Jan. 2, 1951 3 Sheets-Sheet 1

Fig. 2

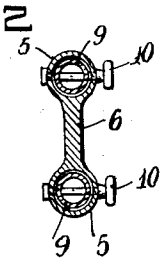
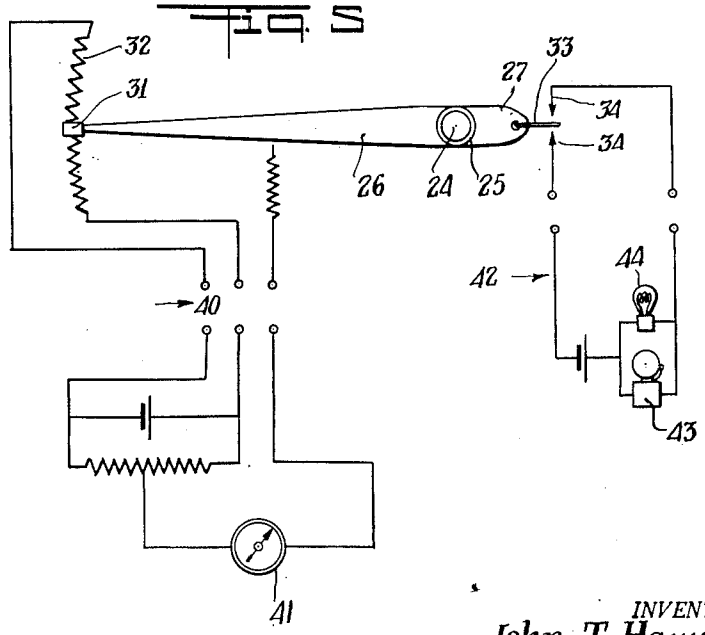


Fig. 3



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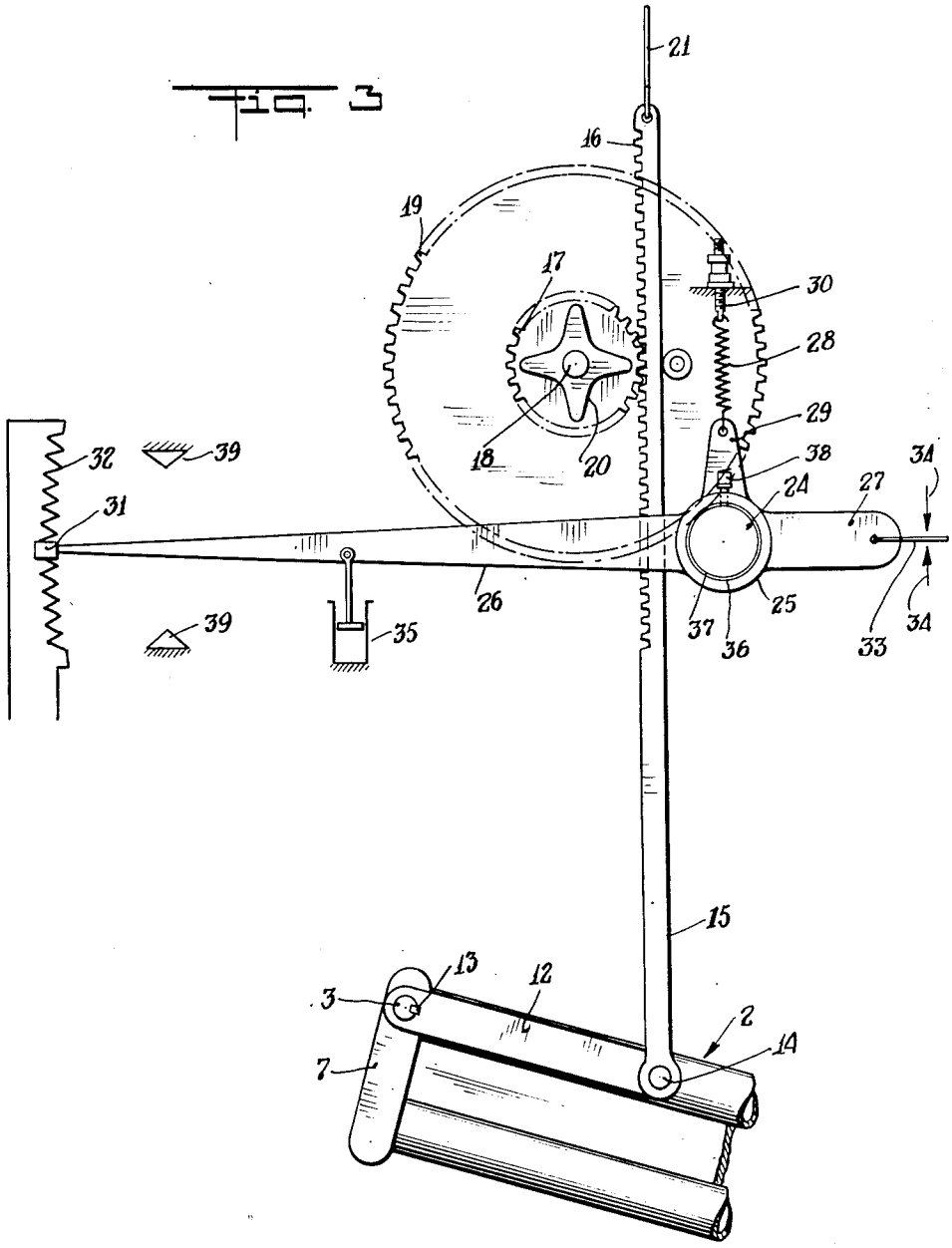
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Fig. 3



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FIG. 4

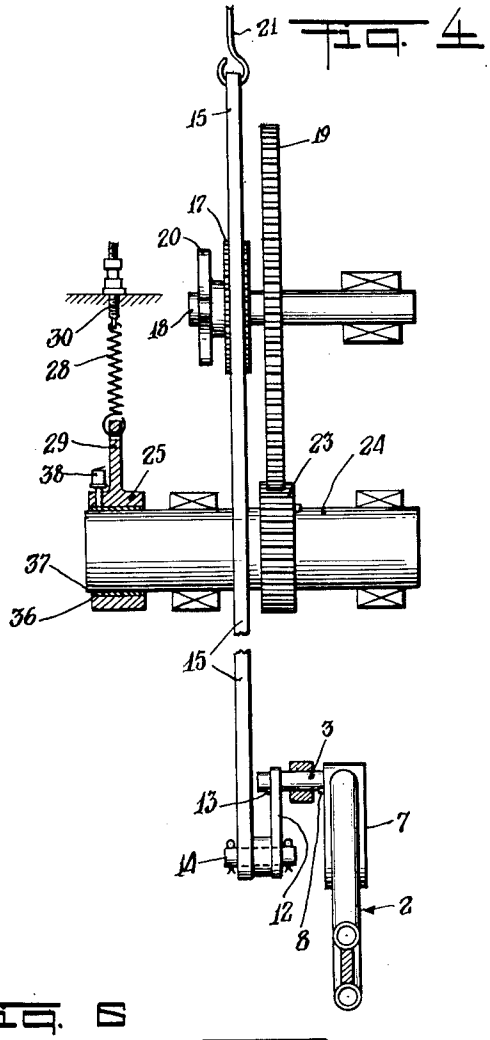


FIG. 6

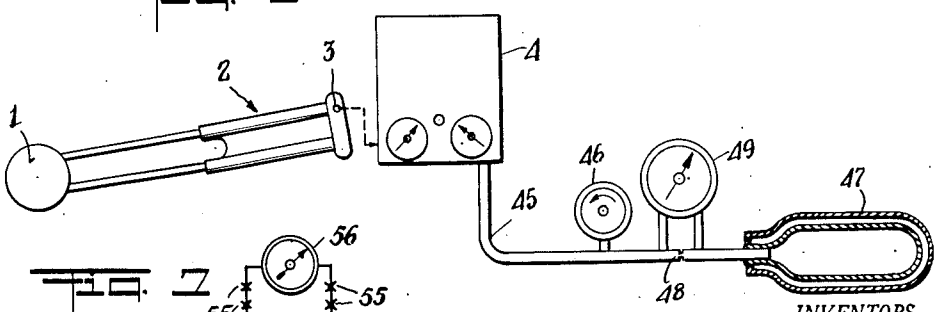
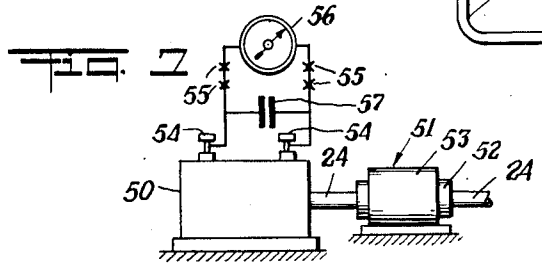


FIG. 7



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UNITED STATES PATENT OFFICE

2,627,178

LIQUID LEVEL RATE OF CHANGE INDICATING DEVICE

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Application January 2, 1951, Serial No. 204,036

3 Claims. (Cl. 73—155)

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This invention relates to apparatus for determining rates of change in the level of a liquid, and particularly the changes in level of the fluid in mud pits of oil, gas and other wells drilled by hydraulic methods, such as that known as the rotary drilling method. The principal purpose of the invention is to bring to the attention of the driller, as rapidly as possible, losses of fluid from the bore hole or the entrance into the bore hole of extraneous fluids, such as gas, oil or salt water.

In the ordinary course of drilling a well by the hydraulic method a hydraulic fluid such as the mud fluid consisting of a suspension of clay or other earthy solids, various weighting and wall plastering materials, in water, is forced down through a string of hollow drill pipe to the bottom of the well, where it is discharged through holes in the bit and thence upwards through the annular space between the drill pipe and the bore hole to the surface of the ground. At the surface of the ground the mud is discharged through a flow line from the mouth of the well to one or more settling pits, from which the mud pumps take suction, returning the mud to the drill pipe, the cycle being continuous.

The functions of this hydraulic fluid are to carry the cuttings from the bit to the surface, to cool the bit as it penetrates the formation, to plaster up and seal the walls of porous formations drilled and, by its hydrostatic pressure, to prevent the ingress of fluids such as gas or salt water into the bore hole from fluid bearing strata encountered during the drilling.

Ordinarily, the weight or specific gravity of the mud fluid is maintained at such a value that its hydrostatic pressure in the hole will exceed the expected pressure in any fluid bearing strata encountered. This will often require a density of as much as 2.0 or more with respect to water. High density, on the other hand, interferes with the drilling and the hydraulic fluid is therefore ordinarily controlled within very close limits so that while preventing in-flow from a traversed strata it will interfere to a minimum extent with the progress of the drilling.

Should in-flow actually occur, drilling is seriously interfered with and in the extreme case the well is lost and serious property damage done due to what is known as a "blow-out." In-flows of salt water dilute the mud fluid and seriously interfere with its wall building and other drilling properties. The salt water being of lower density than the mud fluid normally circulating, a vicious circle is started, the hydrostatic head is reduced and the in-flow accelerated. In extreme cases

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this will result in an artesian well flowing salt water, which generally means the abandonment of the hole and the starting of a new well. If the inflowing fluid is gas the results may be still more disastrous. Very small volumes of gas bleeding, into the column at the bottom of the hole expand as they are carried up in the annular space. This expansion is very great because the pressures at the bottom of the hole in the drilling of oil and gas wells are normally measured in the hundreds of atmospheres. A quantity of gas entering the hole with a volume of one cubic foot, under bottom hole conditions, will therefore, by the time it reaches the surface, have expanded to several hundred cubic feet and will have displaced a quantity of the circulating fluid of equal volume. Such a reduction of the hydrostatic column cannot be tolerated as it would start a vicious cycle and gas would bleed in at the bottom at an ever increasing rate. For this reason it is very important to detect the entering into the bottom of the hole of very small volumes of gas, and long before they have reached the surface where they could be detected by other means.

Another important property of the mud fluid is what is known as its wall building characteristics. During the course of drilling many porous strata are encountered and since the hydrostatic head in the hole is normally, for reasons already explained, maintained in excess of that in the formations, the fluid circulating in the hole would rapidly be lost into the formations unless the exposed faces of said porous formations were rapidly rendered more or less impermeable. The circulating fluid is, therefore, composed of fine clay particles normally added during the ordinary course of drilling and, in addition, bentonitic material obtained from an external source is added in order to bring the wall building ability up to the proper figure. In extreme cases these materials are supplemented by the addition of such things as starch, cottonseed hulls, flakes of Cellophane, and various other appropriate materials. Should the wall building properties of the circulating fluid fall below that required to maintain leakage into the formations at a minimum figure, circulating fluid would be lost to the formations. Such losses are costly since the fluid is expensive and, in addition, can seriously interfere with the drilling since they induce caving and retard the carrying of cuttings to the surface. In serious cases where returns are lost, that is to say, where the loss to the formation exceeds the rate at which fluid is

being pumped into the drill pipe, the level in the hole may fall below the surface, abruptly reducing the hydrostatic head and all too frequently leading to a "blow-out."

It is important, therefore, to determine at all times whether fluid is being lost from the hole or whether external fluids are entering the well. Since, owing to its nature, it is extremely difficult to meter this mud fluid, the determination of loss or gain in the hole is generally made by watching the level in the surface mud pit or tank. It will be obvious that since the circulating system is a closed one that any loss or gain in the hole will be reflected by a change in the level of the mud in the pit or pits at the surface. In earlier drilling days these changes in level were ordinarily determined by such crude methods as marks on the side of the pit, or upon an upright stick in the center of the pit. The mud pit ordinarily cannot be seen from the driller's position, or from the derrick floor, so that more recently, as the importance of accurate determination has become appreciated, instruments have been added which usually consist of a float connected by some means or other to a recorder. Changes of up to five or more feet in level of the fluid in the mud pit or tank are usually covered by these instruments and recorded on a 10" circular chart. Interpretation of the records is complicated by the fact that it is frequently necessary to add water to the circulating fluid, either to reduce its density or viscosity and at other times undesirable components must be extracted from the circulating system.

Mud pits or standard mud tanks are generally around six feet deep, eight feet wide, and thirty feet long. Such a tank has a capacity of a little over three and one-half (3½) barrels to the inch.

A loss of fluid from the hole or, alternatively, entrance of extraneous fluids at the rate of 3½ barrels per hour, if maintained for more than a few minutes, can indicate serious conditions. It is, therefore, very important to detect losses or gains of such magnitude within a period of minutes after they commence. Detection of the corresponding changes in level in the mud tank can be made by continuous careful observation of marks in the tank or of the usual mud level recorder if it is continued for a period of, say, one-half hour or more. To do this would involve keeping an observer continuously at the mud pit, which is generally some distance from the derrick floor, or if an instrument is used, would require that the driller keep an eye constantly upon it. Neither of these conditions are anything like as easy as might at first sight appear, since the driller's attention is fully occupied with other aspects of the drilling operation and, in any case, the time required to make a determination is too long to permit remedial measures to be taken in proper time.

It is, therefore, a principal object of this invention to provide an apparatus that will detect all rises or falls in the level of the mud pit within a few minutes after they start and, concurrently, will provide a clear instrumental indication of the rate of such rises or falls. A second object of the invention is to draw the driller's attention to the fact that the level is rising or falling faster than a predetermined rate by means of attention-attracting visible or audible signals.

A more specific object is to provide means for determining and indicating the rate of change of the fluid level in a mud pit or tank.

Other more specific objects of this invention will be readily apparent from the following detailed description thereof and the accompanying drawings, which illustrate several embodiments of apparatus suitable for practicing the new invention.

In the drawings:

Fig. 1 is a generalized view showing the position in a body of fluid of the float elements employed to actuate the indicating device;

Fig. 2 is a cross-section of the float arm taken along line 2—2 of Fig. 1;

Fig. 3 is a side elevational view of one embodiment of apparatus for indicating the rate of change in level of the fluid;

Fig. 4 is an elevational view looking toward the righthand end of the apparatus shown in Fig. 3;

Fig. 5 is a diagrammatic illustration of electrical indicating circuits employed in connection with the embodiment illustrated in Figs. 3 and 4;

Fig. 6 is a diagrammatic view of another embodiment of apparatus in accordance with this invention; and

Fig. 7 is a generally diagrammatic view of still another embodiment in accordance with this invention.

Referring to Fig. 1, a float 1 is employed which is adapted to float in a body of liquid H, contained in a suitable container C, such as a mud pit or tank, and to rise and fall with the changes in level L of the body of liquid. Float 1 is of any suitable shape, preferably such that its water table is relatively large and its center of buoyancy does not change appreciably with its angle of heel. Float 1 is connected to one end of an arm, designated generally by the numeral 2, the other end of which is keyed to a shaft 3 which projects from an instrument box 4 which houses apparatus responsive to the rotations of shaft 3 and for recording changes in level L, as will be more fully described hereinafter. It will be understood that instrument box 4 will be mounted in any convenient manner on the side of the mud tank or pit but so that float 1 may rise and fall without obstruction in following the changes in level of the body of liquid H.

The arm 2 is telescopic in order that the distance between the center of buoyancy of the float and the shaft 3 can be varied according to the size of the tank. As previously explained, the usual tank has a capacity of around 3½ barrels per inch, but there are tanks used that vary as much as 30% on either side of this figure. The telescopic arm is preferably made adjustable in length so that by appropriate adjustment thereof, a rise of a certain number of barrels in the mud pit will give a pre-selected number of degrees of rotation to shaft 3.

It is important that any change in the level of the hydraulic fluid be accompanied by a corresponding rotation of shaft 3, and since there may be some friction in the bearings of this shaft, and since some power is required to drive the recording equipment associated with apparatus box 4, it is important that the combination of shaft 3 and float 1, considered as a spring, be as stiff as possible. In other words, a small change in level must produce a big change in buoyancy of the float, and this change must be transmitted by a stiff arm to shaft 3. To attain this end, one form of a suitable construction for arm 2 is illustrated in Figs. 1 and 2 wherein arm 2 is composed of a pair of spaced parallel tubular sleeves 5—5 which are connected together lengthwise

by a rigid web 6 and at one end by a transverse end-plate 7 through which shaft 3 extends to form the connection between arm 2 and shaft 3. A key 8 locks arm 2 to shaft 3. A pair of spaced, parallel tubular extension members 9—9 extend slidably into the outer ends of sleeves 5—5 and are rigidly connected at their outer ends to float 1. The telescopically engaged ends of extension members 9—9 and sleeves 5—5 may be connected together by suitable clamping means, such as bolts 10—10, the ends of members 9—9 being provided with a series of axially spaced holes 11—11 to permit axial adjustment of members 9—9 relative to sleeves 5—5 whereby to vary the length of arm 2 as described. It will be understood that the described construction of arm 2 to impart the desired degree of stiffness and longitudinal adjustability is merely exemplary and that any other suitable and more or less conventional construction may be employed to obtain these desired characteristics.

Referring now to Fig. 3, which illustrates the indicating apparatus enclosed within apparatus box 4, a crank arm 12 has one end connected to the inner end of shaft 3, being non-rotatably locked thereto by means of a key 13 in a position parallel to arm 2, so that when shaft 3 is rotated by the angular movement of arm 2 in response to the rise and fall of float 1, crank arm 12 will move through the identical arc in parallel with arm 2. The free end of crank arm 12 is pivotally connected by means of a pivot pin 14 to the lower end of a vertically extending rod 15, provided at its upper end portion with a rack 16. With this arrangement, it will be evident that the vertical movements of rod 15 will be substantially linear with respect to the changes in the liquid level. In other words, a certain change in level L will correspond to a certain vertical movement of rod 15, irrespective of the level at which this change of level takes place.

Rack 16 meshes with a gear 17, which is mounted on a shaft 18, and is connected to drive a larger diameter gear 19, which is also mounted on shaft 18, through the medium of a conventional form of friction clutch device 20, such, for example, as the well-known "star drag" employed on fishing reels and the like. Friction device 20 is incorporated in order that, if for any reason the float 1 and its arm 2 are moved violently, for instance during transportation, the motion will not damage the higher speed parts of the gear train but will merely result in slipping of friction device 20.

The upper end of rod 15 is connected by a cable 21 to a mechanical recorder 22 shown installed on top of apparatus box 4 in Fig. 1. This mechanical recorder may be any one of the well known mechanically operated types and provides a record against time of the vertical position of rod 15, Fig. 2, and therefore of float 1, and consequently of the level of liquid in container C. Such records are useful for reference purposes although, as explained earlier, they do not fulfill the purpose of this invention.

Gear 19 meshes with a gear 23 rigidly connected to a shaft 24 (Fig. 4). The outer end of shaft 24 is surrounded by a sleeve 25 with which is incorporated an elongated pointer 26. Sleeve 25 and its pointer are free to turn on shaft 24 in a manner to be described later. Pointer 26 is counter-balanced by an extension at 27 in order that it and the sleeve 25 may float on the shaft 24 and at the same time be statically and dynamically balanced. This insures that the position of the pointer 26 will be affected a minimum amount by vibration. A coil spring 28 is connected to the upper end of a lug 29 which extends upwardly from sleeve 25, the upper end of spring 28 being anchored to a vertically adjustable screw 30 by which the tension in spring 28 may be adjusted as desired. Spring 28 tends to return the pointer to the middle position after it has been displaced in either direction. This spring, in addition, supports a large part of the weight of pointer 26 and sleeve 25 in order that the latter may float on shaft 24. Pointer 26 is equipped at one extremity with a slider 31 which operates on an electrical resistor 32, of generally conventional type. In this manner the position of pointer 26 can be transmitted as an electrical signal to a remote point in a manner that will be described later. The outer end of extension 27 is equipped with a flexible switch blade 33 and two adjustable contacts 34—34 positioned on opposite sides of the free end of switch blade 33. These adjustable contacts 34—34 can be pre-set so that when the pointer departs by a pre-determined amount from the middle position, contact is made and an audible or visual signal transmitted to a remote position. A damping means of any conventional design, such as a dash pot 35, is suitably connected to pointer 26 to prevent any unwanted vibration of pointer 26.

Now, returning to the manner in which sleeve 25 and pointer 26 are driven by shift 24. As previously mentioned, sleeve 25 has a clearance fit on shaft 24 and if there were no friction, shaft 24 could revolve in either direction without displacing the pointer. According to the present invention the clearance space 36 between shaft 24 and sleeve 25 is filled by a viscous fluid, indicated by the numeral 37, such as Dow Corning 200 fluid. The film between the shaft and the sleeve is maintained by a lubricator 38 mounted on sleeve 25 and communicating with the clearance space 36, which is filled from time to time to maintain the supply of liquid in the clearance space. Owing to the viscous drag of the fluid in the clearance space, rotation of shaft 24 in either direction will tend to cause displacement of pointer 26 in the corresponding direction. Such displacement will be resisted by spring 28, with the result that pointer 26 will take up some position, dependent upon the dimensions of shaft and sleeve, the viscosity of the fluid and the angular velocity of shaft 24. As previously described, the angular velocity of shaft 24 varies directly as the vertical velocity of float 1. Stops 39, disposed on opposite sides of pointer 26, limit the extreme movement of pointer 26. The connection between shaft 24 and sleeve 25 may be termed "fluid friction coupling."

The departure of pointer 26 from the mid-position depends upon the dimensions of the shaft and sleeve, the restoring force of spring 28, the viscosity of the fluid in the annular space 36, and the sense and magnitude of the angular velocity of shaft 24. At constant temperature, the spring, the clearance and the viscosity do not vary and there would, therefore, be a unique position of pointer 26 for every angular velocity of shaft 24, and therefore, for every rate of rise or fall of the level in container C.

By proper choice of the fluid and of the materials of which shaft 24 and sleeve 25 are made, the apparatus can be given automatic temperature compensation. We have found Dow Corning silicone fluids suitable for this purpose. It is well known that the viscosities of these silicone fluids

vary only about one percent as much as that of petroleum oils with changes in temperatures. By use of dissimilar metals for shaft 24 and sleeve 25, and suitable choice of the clearance, the change in viscosity of the silicone fluid can be properly compensated. This compensation can be obtained by using, for instance, steel for sleeve 25 and aluminum or brass for shaft 24. To give an example:

Coefficient of expansion, aluminum $=12.3\times10^{-6}$ per degree F.
Coefficient of expansion, steel $=6.4\times10^{-6}$ per degree F.
Difference $=5.9\times10^{-6}$ per degree F.

Let the aluminum shaft radius be 0.688'' and the clearance at 75° F. be .0005'', then at 150° F. the clearance will be:

$$.0005-(5.9\times10^{-6}\times.683\times75)=.0005''-.0003''=.0002''$$

The ratio, therefore, of the clearance at 75° F. to that at

$$150°\text{ F.}=\frac{.0005}{.0002}=2.5$$

Now, the viscosity of Dow Corning fluid increases in the ratio of 2.5 to 1.0 in cooling from 150° F. to 75° F. The mechanism may, therefore, be automatically compensated for temperature changes in this manner.

While we have found silicone fluids to be particularly useful for the purposes of this invention, it will be evident that other fluids of suitable viscosity and viscosity index characteristics may be employed.

As shown above, there will be a unique position of pointer 26 for every rate of rise or fall of level in the pit and since slider 31 is attached to pointer 26, there will be a unique position of this slider on resistor 32. This may be transmitted as an electrical signal to the driller's position by the generally conventional electrical circuit, indicated at 40, shown in Fig. 5 in which 41 designates a suitable indicating or recording instrument which may be located adjacent the driller's position. Instrument 41 may be calibrated to display the rate of change in the liquid level as, for example, in inches per minute or per hour, or on any other suitable scale. Also, as was previously noted, contacts 34—34 may be set relative to switch blade 33 to close at any pre-determined rate of change in level L in pit C, whereby to transmit an electrical signal by means of the generally conventional electric circuit, indicated at 42, to produce an audible or visible signal, as by means of buzzar 43 or light 44, to draw the driller's attention to the reading on instrument 41.

It will be obvious that a signal corresponding to the position of sleeve 25 and therefore of the rate of rise or fall of the level in the pit could be transmitted to the driller's position by any of the well known means, such as by selsyn or by an air transmitter.

It will also be obvious that the instantaneous angular position of shaft 24 could be transmitted by any well known means to a corresponding shaft mounted in an apparatus box adjacent to the driller's position, said apparatus box including a sleeve, spring and viscous fluid system similar to that already described. A pointer driven through suitable multiplication from the sleeve would then indicate to the driller the rate of rise or fall in the pit.

Fig. 6 illustrates more or less diagrammatically another embodiment in accordance with this invention, by which the rate of change of level L may be readily determined and indicated or recorded for information of the driller. In this embodiment float arm 2 is suitably connected to a conventional form of so-called "pneumatic transmitter," the details of which are well understood by those skilled in the instrument art and which, of themselves, form no part of this invention. A suitable transmitter of the type contemplated is model No. 226R, manufactured by Taylor Instrument Company, Rochester, N. Y., and described in detail in its Bulletin 98,156, March 1947. Transmitters of this type are adapted to vary the pneumatic pressure, such as air pressure, in a line 45 leaving the instrument (which is illustrated as housed in apparatus box 4) in accordance with the position of float 1 and its arm 2. The change of pressure in line 45 corresponding to the change in position of float 1 may be indicated or recorded on a suitable instrument 46 connected to line 45 and placed adjacent to the driller's position. Instrument 46 will correspond in general to recorder 22 of the previously described embodiment and will at all times show the position of float 1 and, therefore, the actual level of liquid in the pit, which indication, while useful, will not show the rate and direction of the change in level in accordance with the principal objects of the present invention. In order to accomplish the purposes of the present invention, line 45 is connected to terminate in a closed chamber 47, which may be double-walled and insulated to minimize temperature effects. A throttling orifice 48 is installed in line 45 in advance of its entrance into chamber 47 and a differential gage 49, of generally conventional and well known design, is connected to line 45 across orifice 48. Under static conditions, the pressure in chamber 47 and line 45 will have become stabilized and there will, therefore, be no difference in pressure on the opposite sides of orifice 48 and no differential will, therefore, be registered by differential gage 49. Assume now that there is a rise in level of liquid H in pit C. This will be accompanied by a corresponding rise in the position of float 1 and the pneumatic transmitter will be actuated thereby to cause a corresponding change in pressure in line 45. The flow restriction provided by orifice 48 will prevent this change in pressure from being transmitted immediately to chamber 47 and a difference in pressure will thereby be created in line 45 on opposite sides of orifice 48. This difference in pressure will be shown by the indication on differential pressure gage 49. The more rapidly float 1 rises or falls, the more rapidly will the pressure change in line 45 and depart from that in chamber 47. Differential gage 49 will, therefore, reflect an indication corresponding to the rate of the rise and fall of the level of liquid in pit C. By suitable calibration of the scale of gage 49, the indication may be made to appear in any rate terms desired.

Fig. 7 illustrates still another embodiment in accordance with this invention by which the rate of change in level may be readily determined and indicated or recorded for information of the driller. In this embodiment shaft 24 is directly connected to a direct current generator 50, of generally conventional design, which is preferably of the permanent magnet type, preferably having skewed armature slots in order to smooth out the required torque, and in which the armature is wound with a large number of turns in order that the ratio of voltage to angular velocity

shall be high, and also preferably having a large number of commutator bars in order to minimize ripple. Such generators are well known and commercially available, and the details thereof do not, of themselves, form a part of this invention. A damping means, designated generally by the numeral 51, is applied to shaft 24 to control non-significant oscillations of the shaft which might result from vibrations of the float and float arm due to vibrations around the drilling rig. In the embodiment illustrated in Fig. 9, the damping means comprises a cylinder 52 which is rigidly mounted on shaft 24 and arranged to rotate inside a fixedly positioned concentrically mounted tubular sleeve 53 with a small amount of annular clearance therebetween. The annular space between cylinder 52 and sleeve 53 will be filled with a viscous liquid similar to liquid 37, described above. The drag created by this liquid between the adjacent surfaces of cylinder 52 and sleeve 53 will effectively damp the rotations of shaft 24.

The output from generator 50 will be applied through terminals 53—53 through leads 55—55 to a generally conventional electrically operated registering device 56, which may be an indicating and/or recording meter, and which may be installed at a point convenient to the driller's position. This meter should be highly damped within itself and, in addition, should have its critical damping resistance equal to, or greater than, that of the generator. In order to supplement the viscous damper 51, we have found it advantageous to shunt a large condenser 57 across leads 55—55.

With this embodiment it will be evident that the amount of electrical current generated by generator 50 and transmitted to register 56 will correspond directly to the rate of rotation of shaft 24, which will, in turn, correspond to the rate of change of level L of liquid H.

By means of the above described invention, it will be evident that the magnitude and direction of the rate of change in the level of the liquid may be readily detected and indicated or recorded, as desired.

In each of the above-described embodiments it will be evident that the float is connected to a transmission means which will produce a linear response corresponding to the positions of the float which may be suitably registered to show the level of the liquid; and that this linear response may be employed to actuate mechanism which will produce a second response corresponding to the rate of change in the movements of the float, which second response may also be suitably registered to show the rate of change in level of a liquid.

It will be understood that various alterations and changes may be made in the details of the illustrative embodiments, above described, without departing from the scope of the appended claims but within the spirit of this invention.

What we claim and desire to secure by Letters Patent is:

1. A liquid level rate of change indicating device, comprising, a float means adapted to rise and fall with changes in level of a body of liquid, a shaft rotatively driven by said float in accordance with the movements thereof, a direct current generator driven by said shaft, and means to record the output of said generator.

2. A liquid level device according to claim 1 having a damping means connected to said shaft.

3. A liquid level device according to claim 1 having a damping means connected to said shaft, said damping means comprising, a cylinder fixed to rotate with said shaft, a stationary sleeve concentrically surrounding said cylinder and providing a small annular clearance space therebetween, and a viscous damping liquid filling said clearance space.

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