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APPARATUS FOR TREATING WELLS

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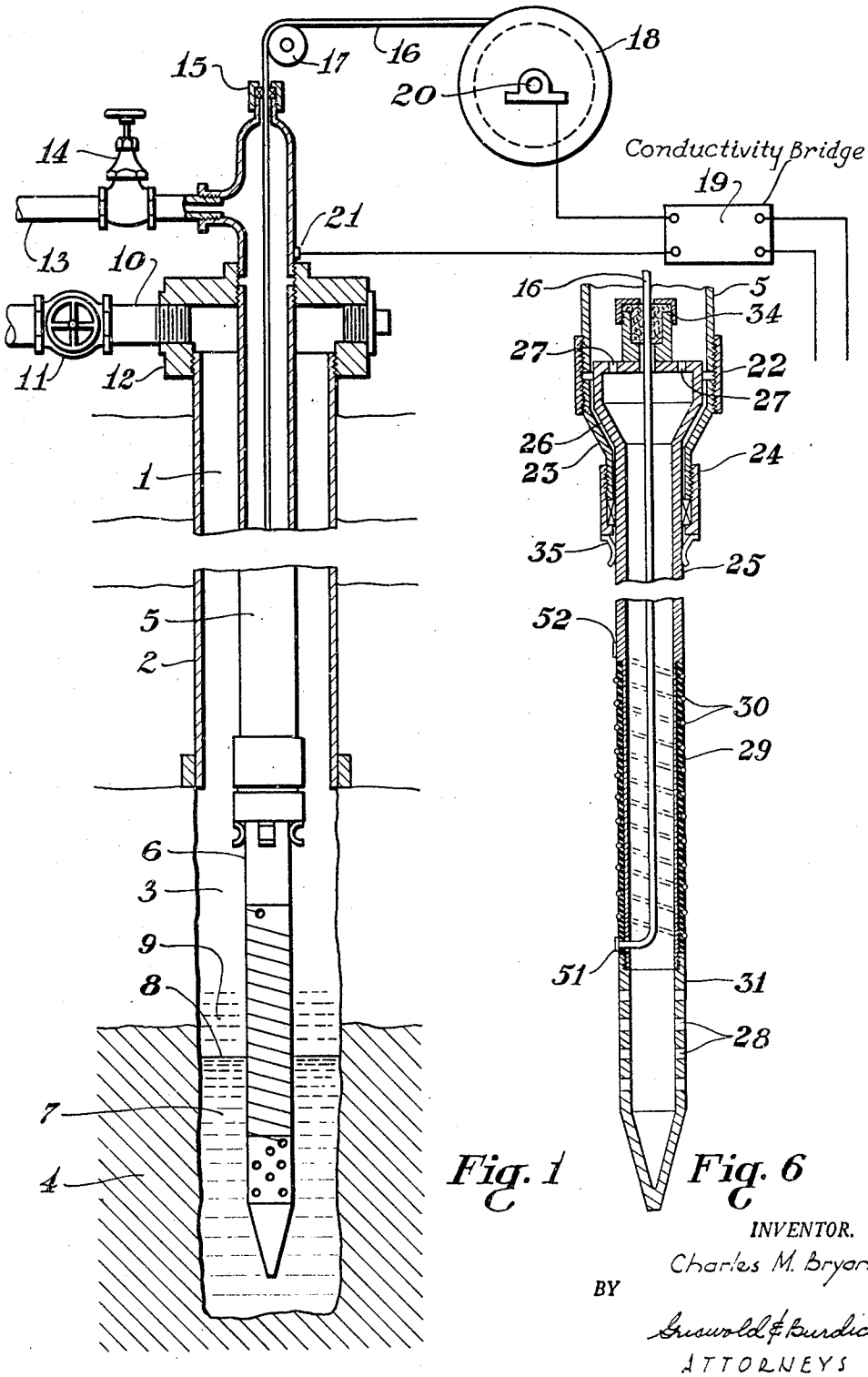


Fig. 1 Fig. 6

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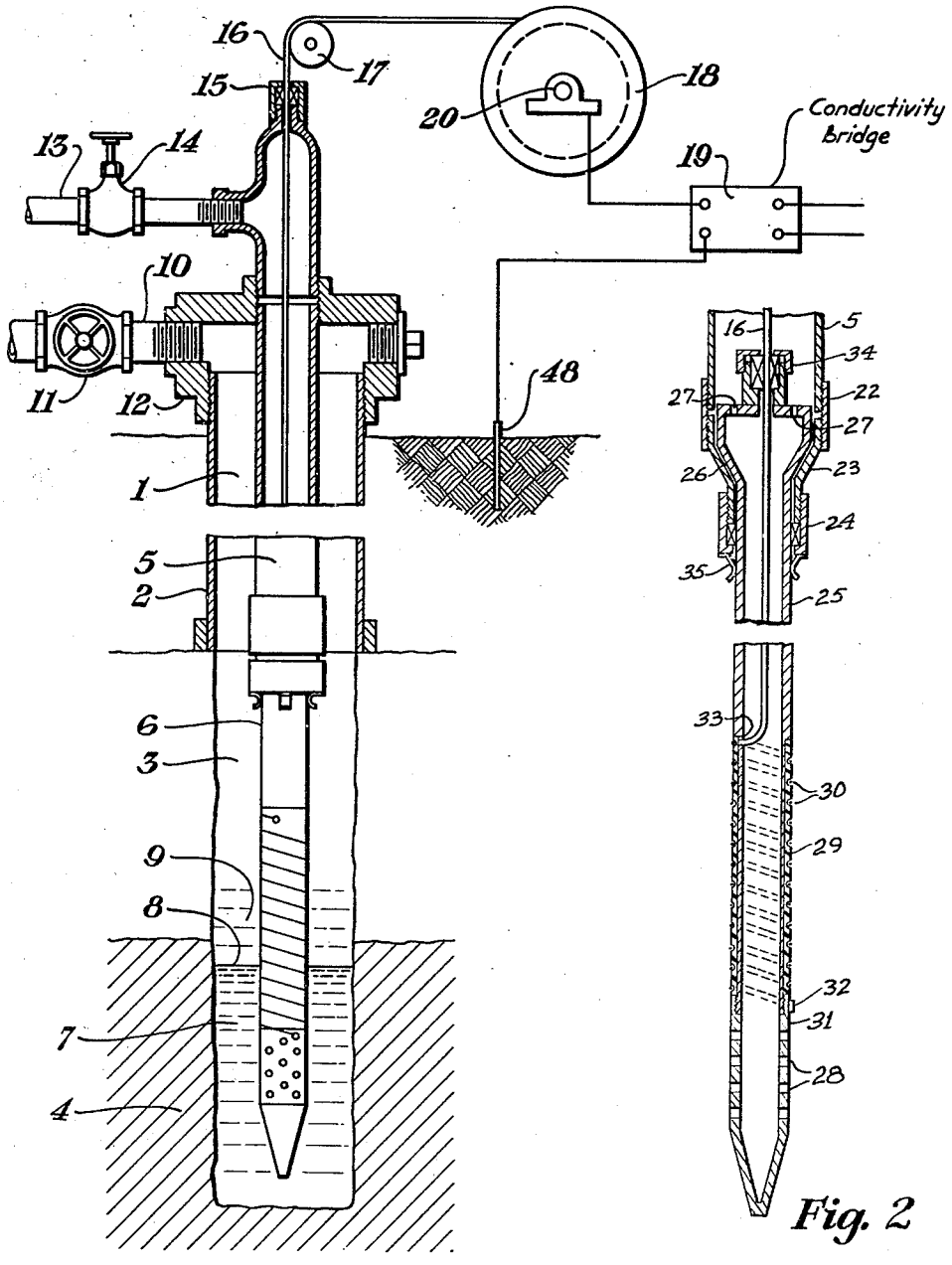


Fig. 5

Fig. 2

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APPARATUS FOR TREATING WELLS

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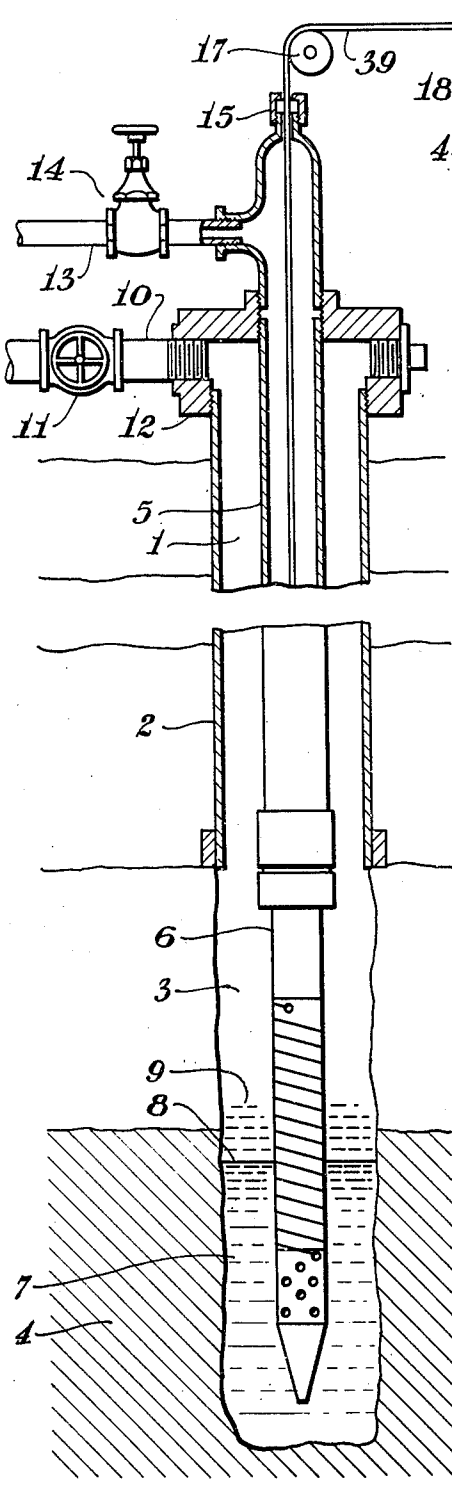


Fig. 3

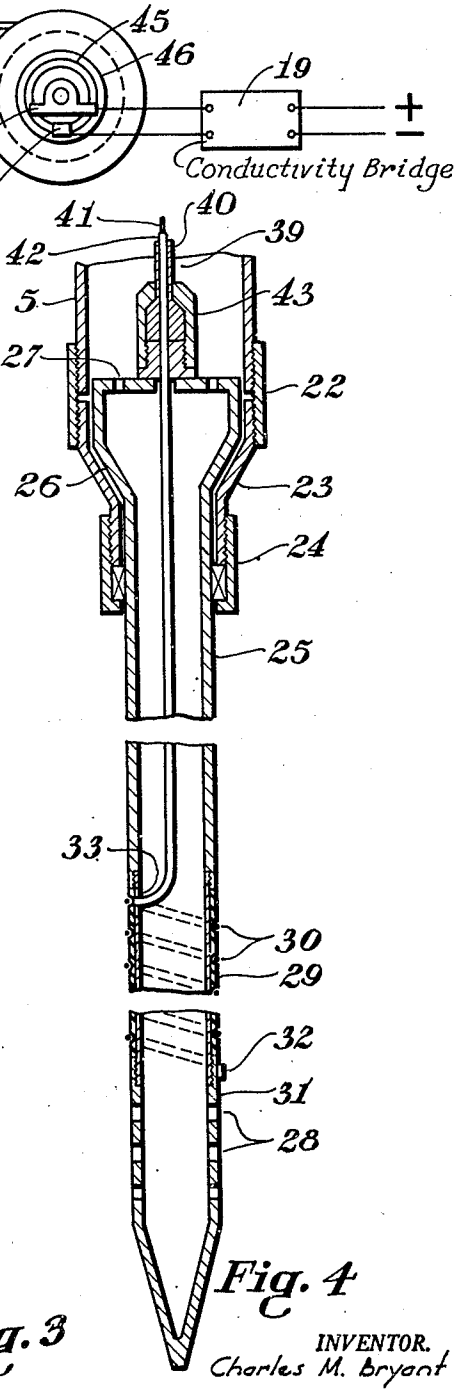


Fig. 4

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UNITED STATES PATENT OFFICE

2,381,875

APPARATUS FOR TREATING WELLS

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Application September 19, 1941, Serial No. 411,442

6 Claims. (Cl. 73—151)

The invention relates to an apparatus for treating the earth or rock formations penetrated by a well bore. It more particularly concerns an apparatus whereby the position of an acid solution or other liquid in the well bore can be accurately ascertained at all times during treatment.

In introducing liquid agents into an earth or rock formation, such as, for example, when introducing an acid solution into the porous calcareous productive formation penetrated by the bore of an oil well, it is the conventional practice to attempt to control the level to which the acid rises during its introduction by maintaining the acid solution under a column of oil as it is forced into the formation. However, it oftentimes happens that the formation adjacent a portion of the oil column is highly porous allowing the oil to escape into the formation, with the result that the acid rises in the well bore and escapes into a section of the formation which may be of an unproductive nature or already porous. Waste of the treating solution thus occurs. In addition, it sometimes happens when carrying out such a treatment that the acid may rise in the well bore during treatment to a point where it attacks and disintegrates the cement around the casing, necessitating another cementing operation before the well can be satisfactorily produced.

An object of the invention is to provide an apparatus which may be suitably used to measure the level to which an electrically conductive liquid rises in a well bore during its introduction into the earth and rock formation surrounding the well bore.

Other objects and advantages of the invention will be apparent during the course of the following description.

The invention, then, consists in the apparatus hereinafter more fully described and particularly pointed out in the claims, the accompanying drawings and following description setting forth in detail one mode of carrying out the invention, such mode illustrating, however, but one of various ways of carrying out the invention.

In the drawings:

Figure 1 is a diagrammatic view partly in section of an oil well equipped for carrying out an acid treatment using the apparatus of the invention.

Figure 2 is a detailed view in cross section of the lower portion of the level measuring device shown in Figure 1.

Figure 3 is a diagrammatic view partly in section showing a modification of the structure of Figure 1.

Figure 4 is a detailed view in cross section of the lower portion of the level measuring device shown in Figure 3.

Figure 5 is a diagrammatic view, partly in section, illustrating still another modification of the structure of Figure 1.

Figure 6 shows the structure of Figure 2 in slightly modified form.

As shown in Figure 1, the upper portion 1 of the well bore is cased with metal pipe 2, while the lower portion 3 of the well bore is uncased and ends in productive stratum 4. Extending from the well tubing string 5, with its lower end adjacent the productive stratum 4, the fluid level measuring device 6 is shown in position for carrying out the acid treatment in accordance with the invention. The lower portion 3 of the well bore is shown filled with acid solution 7 up to a point 8 adjacent the upper level of the productive stratum. The remainder of the well bore is shown filled with a pressuring fluid 9, such as oil. Above the ground level, pipe 10, controlled by valve 11, communicates with the interior of the well through casing head 12, while pipe 13, controlled by valve 14 communicates with the well bore through the tubing string 5. Extending through packing gland 15 attached to the upper end of tubing string 5, insulated conducting cable 16 passes over sheave 17 to carrying reel 18. The conducting cable 16 acts to carry electric current to the measuring device and serves as a means whereby the measuring device may be raised and lowered in the tubing string. An electric circuit is employed in connection with the measuring device 6 for the purpose of indicating the level of the acid in the well bore, and may, as shown, consist of a source of alternating current, such as a 25 or 60 cycle 110 volt alternating current source, the terminals of which are connected to a Leeds and Northrup or other suitable alternating current conductivity bridge 19. One lead from the conductivity bridge is connected to reel shaft 20, which in turn is in electrical contact with cable 16. The other lead from the conductivity bridge is connected to the tubing string 5 by clamping means 21. In the more detailed view of the measuring device shown in Figure 2, a conventional iron collar or coupling 22 is threaded to the lower end of the tubing string 5 and to a tapered seat member 23. Attached to seat member 23 in screw threaded

engagement therewith is a packing gland 24, through which tubular body member 25 of cylindrical shape can be slidably moved in sealing relationship. The tubular body member 25 of the measuring device, formed of metal or other electrically conducting material, is shown enlarged at the upper end to form a tapered seating portion 26 which conforms to the inner surface of seat member 23, thus producing a seal when the surfaces are maintained in contacting relationship. Entry ports 27 and exit ports 28 are provided at the upper and lower ends, respectively, of the tubular member 25 and serve as a means whereby liquid can enter the well bore from tubing 5. A section of the tubular member 25 carries an electrically insulating shell 29 made of "Bakelite," hard rubber, or the like. The insulating shell is provided with a spiral groove over its entire length in which is wound a resistance wire 30, connected at its lower end to the conducting portion 31 of tubular member 25 at 32. The upper portion of the resistance wire 30 is connected to the insulated conducting cable 16 through an insulating bushing 33. The insulated conducting cable 16 is secured to the top of tubular body member 25 by means of clamp 34 and serves as a means by which the measuring device can be raised and lowered in the well. Spring fingers 35 depend from packing gland 24 and serve as additional electrical contact means between the well tubing and the tubular body member as the latter is raised or lowered through the packing gland.

In the modification shown in Figures 3 and 4 a cable 39 having two conductors 40 and 41, separated from each other by electrical insulation 42, has been substituted for cable 16 having a single conductor shown in Figures 1 and 2. One of the conductors of cable 39 may consist of an outer layer of woven or twisted steel wire 40 which serves to support the level measuring device as it is being lowered into the well. The cable 39 is attached to tubular element 25 by clamping means 43. The outer conductor is grounded to the clamping means 43 and is secured thereto as by soldering, brazing, or the like. The insulated inner conductor extends through the tubular element and is connected to the upper end of resistance wire 30 through the insulating bushing 33. With the arrangement shown in Figures 3 and 4 the spring fingers 35 provided as electrical contacts in Figures 1 and 2 may be eliminated since the well tubing is not used to complete the electric circuit. Instead, the current travels through the outer conductor 40 of cable 39, tubular element 25, conducting liquid 8, resistance wire 30, and inner conductor 41. At the top of the well the cable 39 is carried by reel 18 which is provided with suitable means for electrically connecting the cable conductors to the measuring instrument 19. Such means may consist of a suitable shaft support 44 making contact with the shaft which is in turn connected to one of the cable conductors. The other conductor may be connected to ring 45 insulated from the reel 18 by insulation 46. A brush 47 is provided to maintain electrical contact with the ring 45 as the reel is rotated.

In the modification of Figure 5 the electrical connection to the tubing has been eliminated and, instead, one lead from the conductivity bridge 19 is connected to a ground electrode 48. In other respects the apparatus is identical to that shown in Figure 1.

In Figure 6 the structure of Figure 2 has been modified to the extent that the conducting cable 16 is attached to electrode 51 mounted on the lower end of the insulating shell 29. The upper electrode 52 is mounted on the tubular element 25.

The operation of the measuring device will be best understood from a description of an acid treatment of a well employing the device. In carrying out an acid treatment of a well, for example, using the device illustrated by Figures 1 and 2 the assembled measuring device is positioned in the well bore so that the section 29 carrying the resistance wire will be located in the vicinity of the upper level of the productive stratum 4 which is to be subjected to the action of the acid. The well is then preferably filled with a liquid, such as oil, to render it hydrostatically controllable by pumping the liquid into the well through pipe 13, while valve 11 in pipe 10 is maintained in an open position. After the well has been filled, the introduction of acid into the well through pipe 13 in communication with the tubing 5 is started, while oil is allowed to escape at the casing head through pipe 10. As the acid solution approaches the bottom of the well, current is applied to the electrical circuit, and the bridge is adjusted so that the galvanometer needle shows no deflection, indicating that the bridge circuit is balanced. When the acid reaches the bottom of the well and rises in the bore to a point where it covers a portion of the resistance wire, this portion is shorted out and results in unbalancing the bridge circuit. The bridge is then rebalanced so that the galvanometer again shows no deflection. The change in resistance shown on an indicating dial carried by the conductivity bridge and calibrated in terms of the resistance of the wire carried by the measuring device, serves to indicate the length of wire shorted out by the acid, and thus the level to which the acid has risen in the well bore. After the acid has reached the desired level in the well bore, valve 11 is closed to prevent further escape of oil at the casing head and pressure is applied to force the acid into the formation either by pumping an additional quantity of acid into the well or by pumping oil into the well if the desired quantity of acid has already been introduced. By balancing the circuit from time to time as the acid is being forced into the formation, accurate knowledge of the level at which the acid rises in the well bore is obtained. If at any time during the treatment the acid rises above a desired level, indicating that the pressuring liquid is escaping into the formation, additional pressuring liquid may be pumped into the well through pipe 10 so as to control the level of the acid at any desired point. Also, if the acid level, as indicated by the measuring device, falls below the desired level, indicating that the formation adjacent the lower portion of the well bore is highly porous and that the acid is draining away into this portion of the formation, a quantity of a blanketing medium, such as a solution of an "organic jellifying material" described in U. S. Patent No. 1,998,756, may be introduced into the bottom of the well to prevent such drainage, or, if desired, the rate of introduction of the acid may be speeded up so as to maintain the level of fluid at the desired point.

The operation of the apparatus employing the structure of Figures 3 and 4 is also similar to that described in connection with Figures 1 and 2

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differing, however, in that the well tubing does not serve as a conductor to complete the electrical circuit. Therefore it is unnecessary to provide means to maintain electrical contact between the tubing and the tubular element **25**. As the level of the conducting liquid **7** rises in the bore and contacts the resistance wire the electric circuit is completed between the outer cable conductor **40**, tubular element **25**, conducting liquid **7**, resistance wire **30**, and inner cable conductor **41**.

The method of the operation of the apparatus of Figure 5 is identical with that described in connection with Figure 1. The earth or rock around the well bore being connected to the ground electrode **48** acts as an electrical conductor and thus the path of the current is from the ground electrode **48** through the earth or rock to the acid and tubing.

In the modification shown in Figure 6 the conducting cable **16** is connected to the lower end of the resistance wire at electrode **51**. This adapts the apparatus to detecting the interface between two fluids, the upper one of which has the higher conductivity. This apparatus would be useful where the non-conducting fluid is introduced through the tubing and the tubular element **25** while the conducting fluid is introduced into the well through the casing. In this manner the conducting fluid can be maintained off the bottom of the well bore by the non-conducting fluid and its position may be ascertained from the amount of the resistance wire shorting out as the level of the conducting fluid fluctuates.

While the apparatus has been described and is illustrated as being capable of being raised and lowered during the course of the treatment, this procedure is usually unnecessary, since the section carrying the resistance wire can be made so that it extends the entire length of the well bore over which it is desired to control the level of the acid solution. Thus the packing gland or other similar sealing means allowing the measuring device to be raised and lowered, while being sealed to the well tubing can ordinarily be dispensed with and the measuring device allowed to remain in contacting relationship with the seat during the treatment.

Although direct current may be employed in the electrical circuit, it is generally preferable to use alternating current, since errors due to polarization effects are substantially eliminated. A source of alternating current such as one of 110 volts and 60 cycles may be suitably used. However, it has been found that polarization and capacity effects which adversely affect the accuracy of the measurements can be greatly lessened by employing a source of low cycle square wave alternating current or commutated direct current. A current of this type may be supplied to the circuit by connecting the leads of a battery of dry cells or its equivalent, such as a conventional radio B battery supplying 22.5 volts, to a device adapted to periodically reverse the current, such as a vibrator or a commutator with a motor drive. By suitably regulating the device, low cycle alternating current having square wave characteristics is readily obtained. It has been found preferable to employ a current of this type having from 1 to 5 cycles, although from ½ to 30 cycles may be suitably used. When a current source is employed having low cycle characteristics, such as from between 1 to 10 cycles, the transformer ordinarily included in the circuit of the alternating current conductivity bridge is eliminated and the source of low cycle current connected directly to the Wheatstone bridge circuit.

Resistance wire suitable for use should be of the type whose resistance is little affected by the acid or by changes in temperature. Nichrome wire analyzing about 20 per cent chromium and 80 per cent nickel may be suitably used. Wire having from 4 to 20 ohms of resistance per lineal foot and of from 28 to 34 Brown and Sharpe gauge size is most suitable for the purpose at hand, although wire of other sizes and resistances may be used. In general, from 2 to 4 turns of wire per inch of length of the section of the apparatus carrying the resistance wire has been found to be satisfactory.

In the foregoing manner the treatment of a well with an acid reagent or other electrically conductive liquid or a non-conductive liquid can be carried out much more effectively, since the level or the point of entry of the liquid agent can be accurately determined and controlled at any time during the treatment.

This application is a continuation-in-part of my co-pending application Serial No. 265,049, filed March 30, 1939.

Other modes of applying the principle of my invention may be employed instead of those explained, change being made as regards the means and the steps herein disclosed, provided those stated by any of the following claims or their equivalent be employed.

I therefore particularly point out and distinctly claim as my invention:

1. In a fluid level indicating device for wells, the combination of a tubing string, a tubular member adapted to pass through the tubing string, means carried by the lower end of said tubing string adapted to engage the upper portion of the tubular member in sealing relationship while maintaining electrical contact between the said tubing string and the tubular member, a resistance element longitudinally mounted on the outer surface of the tubular member and electrically insulated therefrom, and electrical circuit means including the resistance element for measuring the change in resistance in the electric circuit as an electrically conducting liquid contacts said resistance element.

2. In a fluid level indicating device for wells, the combination of a tubing string, a seat member carried by the lower end of the tubing string, a cylindrical tubular member capable of being lowered through the tubing string and adapted at its upper end to engage the seat member in sealing relationship while maintaining electrical contact between the tubing string and said tubular member, a resistance wire longitudinally mounted on the outer surface of the tubular member and electrically insulated therefrom, and electric circuit means including the resistance wire for measuring the change in resistance in the electric circuit as an electrically conducting liquid short circuits a portion of said wire.

3. In a fluid level indicating device for wells, the combination of a tubing string, sealing means carried by the lower end of the tubing string, a tubular member adapted to be lowered through the tubing string and slidably mounted in sealing relationship in said sealing means, means for maintaining electrical contact between the tubing string and the tubular member as the latter is moved in the sealing means, a resistance

wire longitudinally mounted on the outer surface of the tubular member and electrically insulated therefrom, and electrical circuit means including the resistance wire for measuring the change in resistance in the electric circuit as an electrically conductive liquid short circuits a portion of said wire.

4. In a fluid level indicating device for wells, the combination of a well tubing string, a seat member carried by the lower end of the tubing string, a packing gland attached to the seat member, a cylindrical tubular member capable of being lowered through the tubing string slidably mounted in the packing gland, spring fingers attached to the packing gland and adapted to contact the tubular member as said member is moved through the packing gland, a resistance wire spirally wound on a portion of the outer surface of the tubular member and electrically insulated therefrom, sealing means on the upper end of the tubing string adapted to allow an electrically insulated cable to be slidably moved therethrough in sealing relationship, and electrical circuit means including the resistance wire for measuring the change in resistance in the electric circuit as an electrically conducting liquid short circuits a portion of said wire.

5. In a fluid level indicating device for wells, the combination of the tubing string, a tubular member adapted to pass through the tubing string, means carried by the lower end of said tubing string adapted to engage the tubular member in sealing relationship, a resistance element longitudinally mounted on the outer surface of the tubular member and electrically insulated therefrom, and electric circuit means including the resistance element for measuring the change in resistance in the electric circuit as an electrically conductive liquid contacts said resistance element.

6. In a fluid level indicating device for wells, the combination of a tubing string, a resistance wire carrying member adapted to pass through the tubing string, a resistance wire mounted on said carrying member in longitudinal relationship, means carried by the lower end of the tubing string adapted to engage the resistance element carrying member in sealing relationship, said resistance element carrying member having a passage therethrough adapted to conduct fluid from the tubing string into the well bore at a point below the lower end of the resistance element, and electric circuit means for indicating when an electrically conducting fluid contacts the resistance element.

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