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April 25, 1944. P. G. SHELLEY 2,347,615

APPARATUS FOR TREATING WELLS

Filed March 2, 1942 2 Sheets-Sheet 1

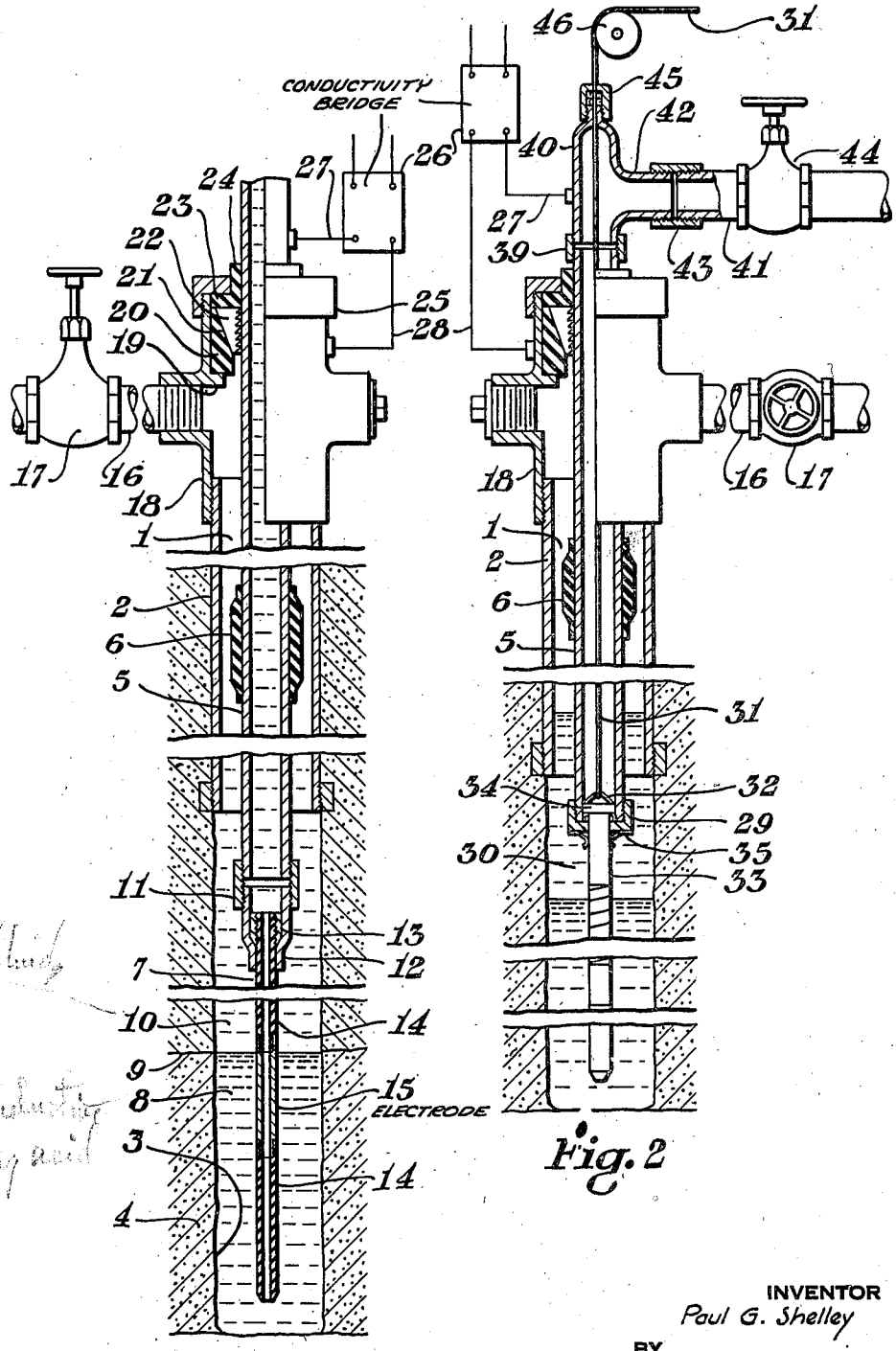


Fig. 1

Fig. 2

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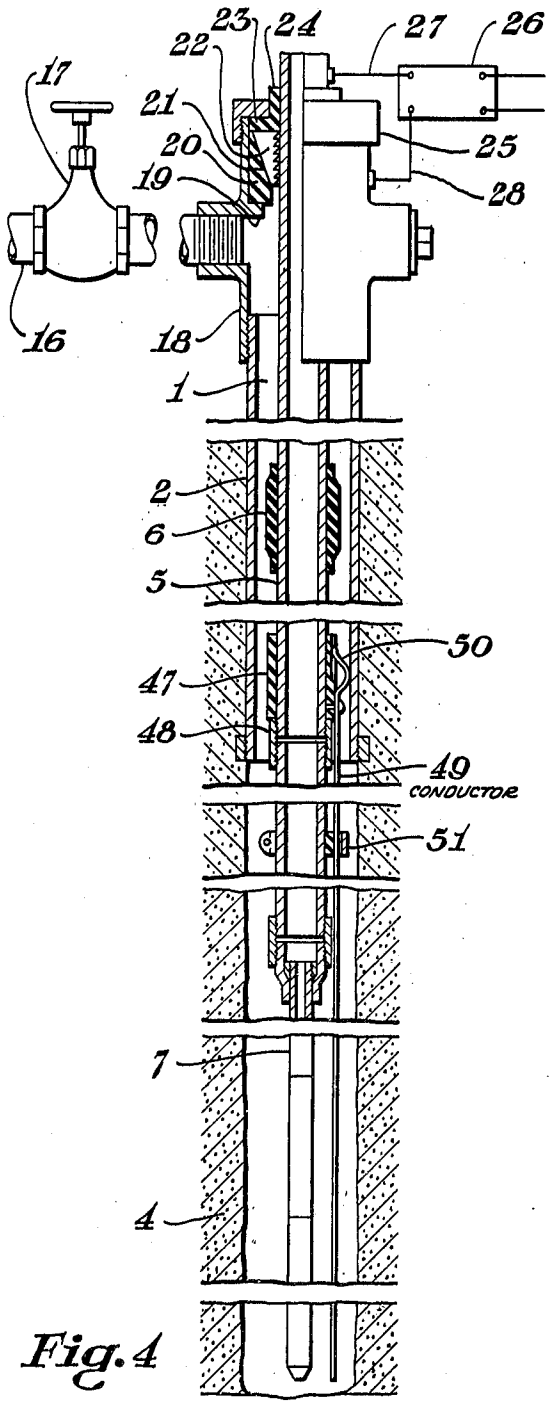


Fig. 4

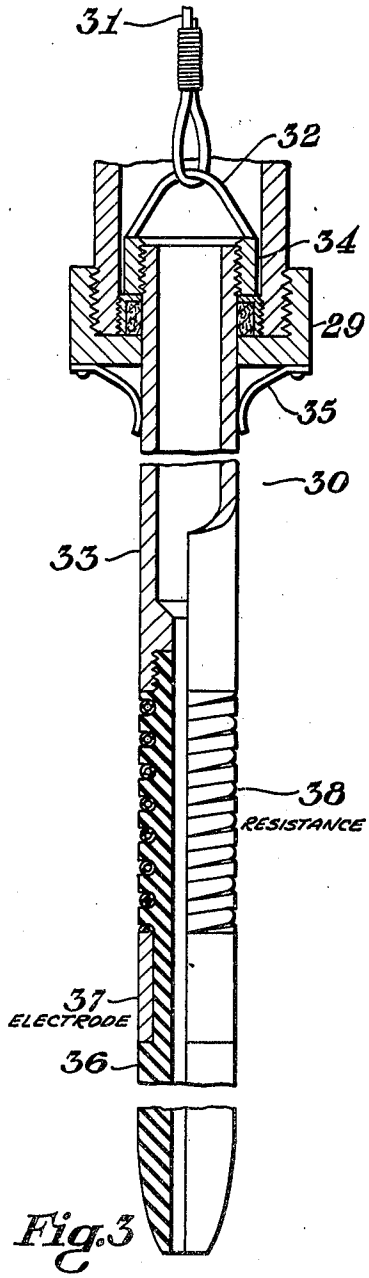


Fig. 3

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UNITED STATES PATENT OFFICE

2,347,615

APPARATUS FOR TREATING WELLS

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Application March 2, 1942, Serial No. 432,941

4 Claims. (Cl. 73—51)

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

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 highly 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.

It is, therefore, the principal object of the invention to provide an apparatus suitable for use in treating a well, whereby the level to which liquid rises in a well bore during its introduction into the earth and rock formation surrounding the well bore can be ascertained at all times during the treatment.

Another object of the invention is to provide an apparatus which may be used to ascertain and control the position of a treating fluid in the well bore at all times during a treatment.

Still another 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 further 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:

Fig. 1 is a diagrammatic view partly in section of the apparatus positioned in a well bore and arranged for carrying out an acid treatment;

Fig. 2 is a diagrammatic sectional view of a modification of the apparatus illustrated in Fig. 1;

Fig. 3 is a detailed view in cross section of the lower portion of the level measuring device shown in Fig. 2; and

Fig. 4 is a diagrammatic view partly in section showing a modification that may be incorporated into the structures of Figs. 1 and 2.

As shown in Fig. 1 the upper portion of the well bore is cased with metal pipe 2 while the lower portion 3 of the well bore is uncased and ends in a productive stratum 4. The tubing string 5 extends into the well and is provided with insulating members 6 disposed in suitable number on the well tubing to insulate the well tubing from the well casing. Depending from the well tubing 5 and positioned adjacent productive stratum 4 the fluid level measuring device, designated by numeral 7 is arranged for carrying out an acid treatment in accordance with the invention. The lower portion 3 of the well bore is shown filled with acid 8 up to a point 9 adjacent the upper level of productive stratum 4. The remainder of the well bore is shown filled with a pressuring fluid 10 such as oil. The lower end of the tubing supports the measuring device 7 by means of a conventional coupling or collar 11 which is connected to tapered seat member 12. The tapered seat member 12 engages a complementary seat member 13 attached to the upper end of tubular element 14. Tubular element 14, made of Bakelite or other similar insulating material is provided with a restricted bore through which the electrically conducting fluid flows to reach the well bore. The tubular element 14 is formed in two sections connected together by means of threaded conducting member 15 which serves as an electrode. Above the ground level pipe 16, controlled by valve 17, communicates with the interior of the well through casing head 18. Casing head 18 is provided with a shoulder 19 on which the insulating ring 20 is adapted to seat. Insulating ring 20 is provided with a tapered shoulder 21 upon which slips 22 are adapted to wedge and engage the tubing 5, thus holding the tubing in the desired position. A second insulating ring 23 is adapted to seat on top of the slips 22 and the insulating ring 20 and

is provided with an upwardly projecting portion 24 which insulates the tubing string 5 from the casing head cap 25 screwed down on top of the casing head 18. An electric circuit is employed in connection with the measuring device 7 for the purpose of indicating the level of the acid or other conducting fluid 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 26. One electrical lead 27 from the conductivity bridge is connected to the tubing string 5 while the other lead 28 from the bridge is connected to the casing 2.

In the modification shown in Fig. 2 a slightly different form of apparatus is used for carrying out the measurement. In Fig. 2 the lower end of the tubing string 5 is provided with a packing gland 29 through which the measuring device 30 is adapted to be raised and lowered in sealed relationship by means of cable 31 attached to eye 32 on the upper end of the measuring device.

As shown in the more detailed view in Fig. 3 the measuring device 30 of Fig. 2 consists of an upper steel tubular element 33 provided with a lug or outstanding flange 34 at its upper end, which is adapted to abut the top of the packing gland 29 and thus prevent the tool from being lowered out of the tubing. Spring clips 35 are attached to the packing gland 29 and are adapted to maintain electrical contact between the well tubing and the steel or other conducting portion 33 of the tool. The lower portion of the tool comprises a non-conducting tubular element 36 provided upon its outer surface with a suitable electrode 37 made of copper or other suitable conducting material. An insulated electrical resistance wire 38 is embedded in a spiral groove formed in the surface of the element 36. The wire 38 is electrically connected to the electrode 37 and the tubular element 33. The lower non-conducting portion 36 of the device is provided with a restricted bore through which acid or other conducting liquid flows into the well.

Referring again to Fig. 2, above the ground the tubing 5 is connected by means of a coupling or collar 39 to a pipe cap member 40 which is suitably connected to conduit 41 through outlet 42 by means of collar 43. Pipe 41 is provided with a valve 44 to aid in closing in the well and controlling the flow of fluid. The cable 31 extends through a suitable packing gland 45 at the upper end of cap member 40 and passes over sheave 46 to a reel not shown.

The modification illustrated in Fig. 4 shows how the structure of Figs. 1 and 2 may be modified by providing a non-conducting insulating bushing 47 which rests on tubing collar 48 provided on the well tubing string 5 at a point adjacent the lower end of the casing. A conducting rod 49 is secured to the insulating bushing 47 and is provided at its upper end with a flared spring finger portion 50 adapted to make contact with the well casing 2. The rod member 49 is suitably secured and insulated from the tubing string 5 below the end of the casing by insulating clamp members 51. The conducting rod 49 is provided of such length as to extend into the well bore to a point adjacent the lower end of the measuring device which may be of the type illustrated in either Figs. 1 or 2. The remaining portions of the apparatus and assembly details follow the description and numerals of Fig. 1.

The operation of the measuring device will best be understood from a description of the acid treatment of a well according to the invention employing the assembled apparatus. In employing the apparatus of Fig. 1, the assembled measuring device is positioned in the well so that the electrode 15 is located near the level at which it is desired to control the fluid. The well is then preferably filled with a liquid such as oil to render it hydrostatically controllable by pumping the oil into the well through the tubing 5 while valve 17 in pipe 16 is maintained in an open position. After the well has been filled, introduction of acid into the well through tubing 5 is started, while oil is allowed to escape at the casing head through pipe 16. As the acid solution reaches the bottom of the well, current is applied to the electric circuit and the bridge is adjusted so that the galvanometer shows no deflection indicating that the circuit is balanced. As acid fills the well bore and contacts the electrode 15, a portion of the restricted acid column flowing through tubular element 14 will be shorted out, changing the resistance in the circuit due to the acid column, and thus causing the bridge circuit to unbalance. This unbalancing of the bridge will indicate that the level of the acid has reached the electrode 15. Further rise of the acid in the well bore may bring the acid up to the seat member 12 which will eliminate further resistance from the circuit and cause further unbalancing of the bridge circuit, and thus the approximate level of the acid in the bore below the tubing can always be ascertained. It will be evident that the path of the electric current is down the well tubing, through the restricted column of acid in tubular member 14, thereafter through any acid in the well bore to the surrounding formation, and through the well casing back to the surface of the earth. The accuracy with which the level can be determined depends on the length of the non-conducting tubular element 14 on each side of the electrode.

It will be apparent that it is only possible to tell that the acid is below the electrode or between the electrode and the lower end of the tubing since the upper insulated section 14 of the tubular member constitutes a high resistance path separating the electrode from the lower end of the tubing, and with the electrolyte level lying below the electrode or between the electrode and the lower end of the tubing, there is no appreciable change in the resistance of the indicating circuit. It has been found that by employing a restricted bore in the tubular element 14 of from about ¼ to ½ inch in diameter, the resistance of from 3 to 12 feet of 15 per cent hydrochloric acid is in the order of about 200 ohms. Since a resistance of this order will ordinarily be large in comparison to the remaining resistance of the circuit, shorting out a substantial portion of the acid column will be readily detected and serves as an indication of the level of the acid. Thus, if at any time during a 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 connections provided for the purpose, so as to control the fluid level at any desired point. Additionally, if the acid level falls below the desired level, indicating that the formation adjacent the lower portion of the well

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bore is highly porous and that the acid is draining away, the bottom of the well bore may be blanketed in a manner well known in the art and described in detail in U. S. Patent 1,998,756. Or if desired the rate of introduction of the acid may be speeded up so as to maintain the level of the fluid at the desired point. After the treatment is completed the tool 7 may be circulated out of the well bore as by pumping fluid into the well through the casing whereupon the tool 7 will be washed or circulated out through the tubing.

The operation of the device shown in Figs. 2 and 3 is very similar to that of Fig. 1. The resistance in the circuit before the acid has risen to contact electrode 37 is mainly the resistance of the restricted acid column in the non-conducting tubular element 36. Upon the acid attaining the level of the electrode 37 the resistance element 38 becomes a part of the electric circuit and thereafter the resistance of the acid column and the resistance of element 38 assume the relation of resistances in parallel. By making the resistance of the insulated resistance wire 38 equal to that of the restricted column of acid in element 36 the effect of acid contacting the electrode 37 will be to reduce the total resistance of the circuit by half, in accordance with the relationship of resistances in parallel set forth in the following equation:

$$R=\frac{R_1R_2}{R_1+R_2}$$

Thus as the level of the acid reaches the electrode 37, the total parallel resistance of the circuit will be reduced approximately one half or at least by an amount equivalent to the total resistance of the resistance wire and the acid column in the restricted passage of the element 36 compared with the resistance of either.

The modification shown in Fig. 4 is adaptable for use in the cases where the resistance of a formation is very high, in which case it is desirable to establish electrical contact with the acid in the bottom of the well and conduct the current back to the casing without current loss due to the high resistance of the formation. The conducting rod 49 serves to carry the current flowing through the acid back to the casing.

In the foregoing manner the treatment of a well with an acid reagent or other electrically conductive liquid can be carried out much more effectively, since the level or point of contact of the liquid can be controlled as the acid treatment progresses.

I claim:

1. In apparatus for introducing into a well an electrically conducting liquid and measuring its level therein, the combination of a casing, a tubing string, insulatons on the tubing string to insulate the same from the casing, a tubular member removably engaging and held in testing position by the lower end of the tubing string and having a restricted bore communicating with the tubing string, an electrode positioned intermediate the length of said tubular member and electrically connected to the tubular member through resistance, electrical connections on said casing and said tubing string, respectively, to a source of current for forming an electric circuit through the tubing and casing which is closed when the bore of said tubular member and well below it is filled with a conducting liquid, means in the circuit for indicating a change in its resistance as the level of the conducting liquid in the well changes to make and break contact with the electrode on the tubular member.

2. Apparatus according to claim 1 in which the electrode is mounted externally upon the tubular member and connected by a resistance winding to the tubing string.

3. Apparatus according to claim 1 in which the tubular member is adapted to pass through and be removably supported in the lower end of the tubing string.

4. In apparatus for introducing into a well an electrically conducting liquid and measuring its level therein, the combination of a casing, a tubing string, insulators on the tubing string to insulate the same from the casing, a tubular member removably engaging and held in testing position by the lower end of the tubing string and having a restricted bore communicating with the tubing string, said tubular member having a mid-section of electrically conducting tubing and end sections of non-conducting tubing, electrical connections on said casing and said tubing string, respectively, to a source of current for forming an electric circuit through the tubing string and casing which is closed when the bore of said tubular member and well below it is filled with a conducting liquid, means in the circuit for indicating a change in its resistance as the level of the conducting liquid in the well changes to make and break contact with either the mid-section of the tubular member or the tubing string.

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