

[54] OIL WELL TOOL FOR MEASURING
PERCENT OIL

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[51] Int. Cl. G01n 27/42, G01v 3/00
[58] Field of Search 324/2, 10, 11, 30 R, 30 B,
324/62 R, 65 R

[56] References Cited

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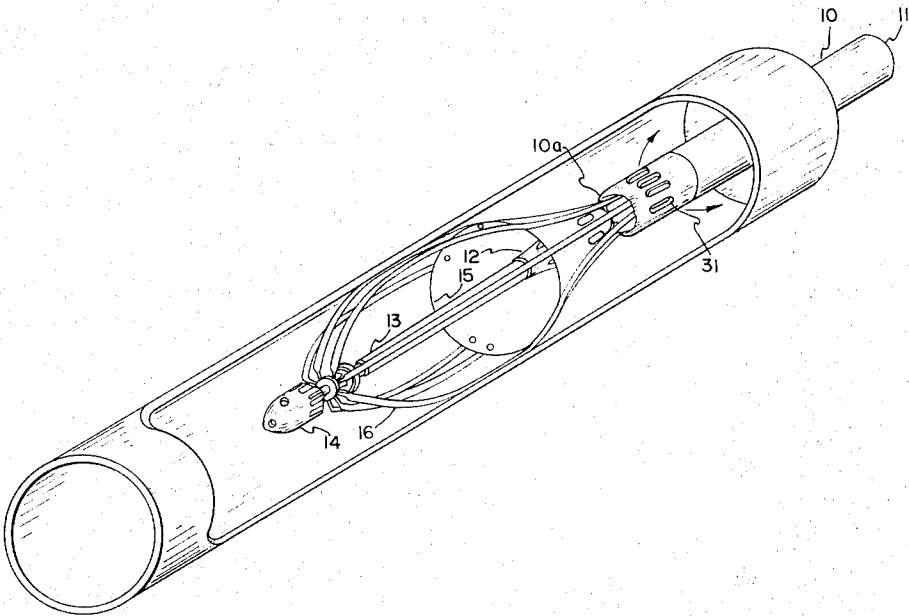
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Attorney, Agent, or Firm—Paul D. Flehr et al.

[57] ABSTRACT

A tool for measuring the percent of oil in an oil/water mixture in an oil well. A plurality of electrodes are arranged in a substantially coextensive array in the flow path of the produced mixture at varying levels. Electrical arrangements are provided whereby a statistical analysis of the number of electrodes immersed in oil at a given moment may be integrated on a go-no go basis, the electrodes being either insulated when in oil or conducting to ground when in water. The number of electrodes so insulated by oil droplets being converted into an analogous electrical signal. Errors due to variations in the resistance and galvanic offset voltage in the water are compensated for.

8 Claims, 14 Drawing Figures



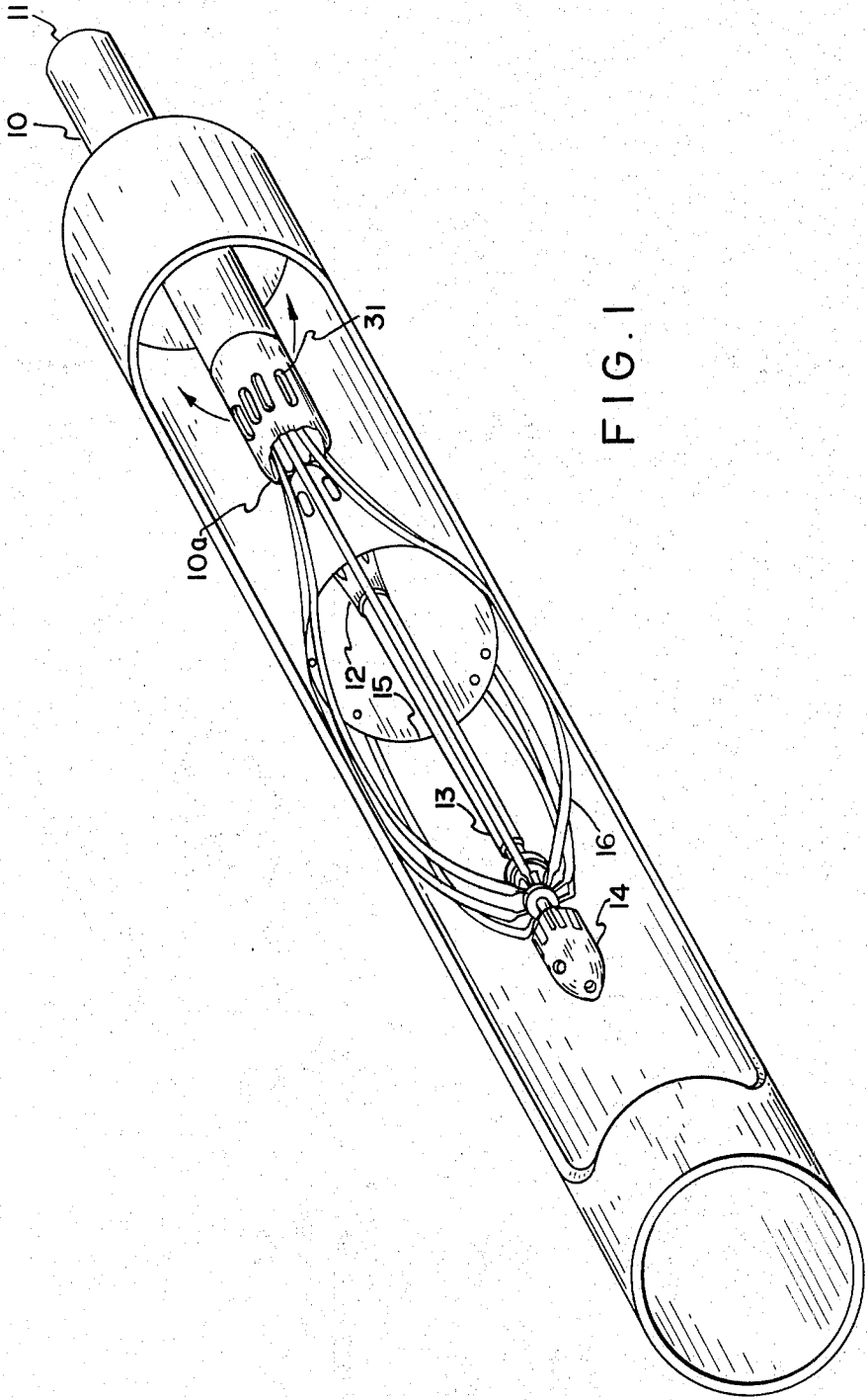


FIG. 1

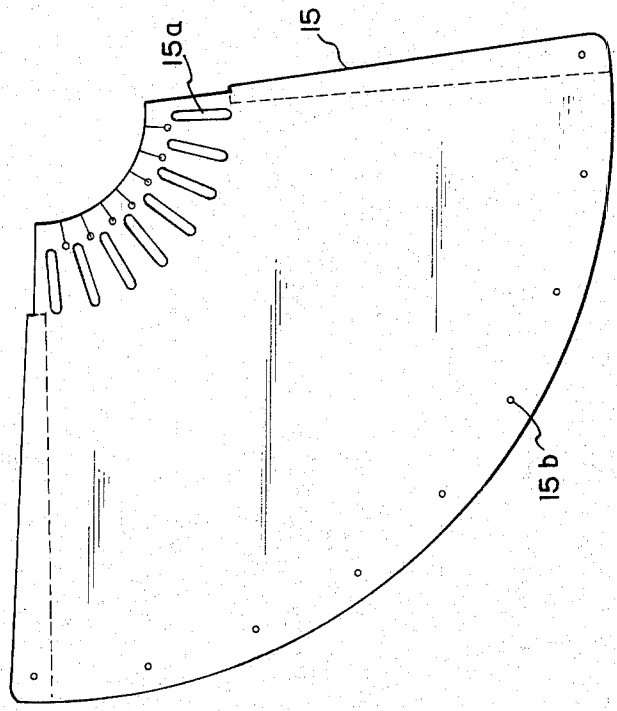
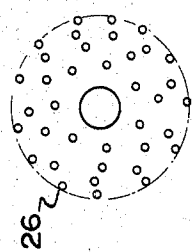
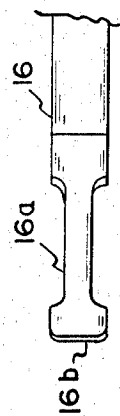
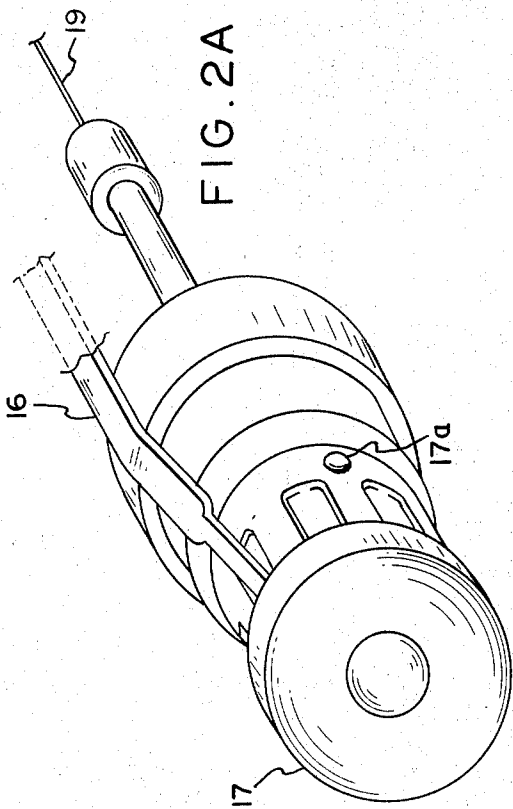


FIG. 2E

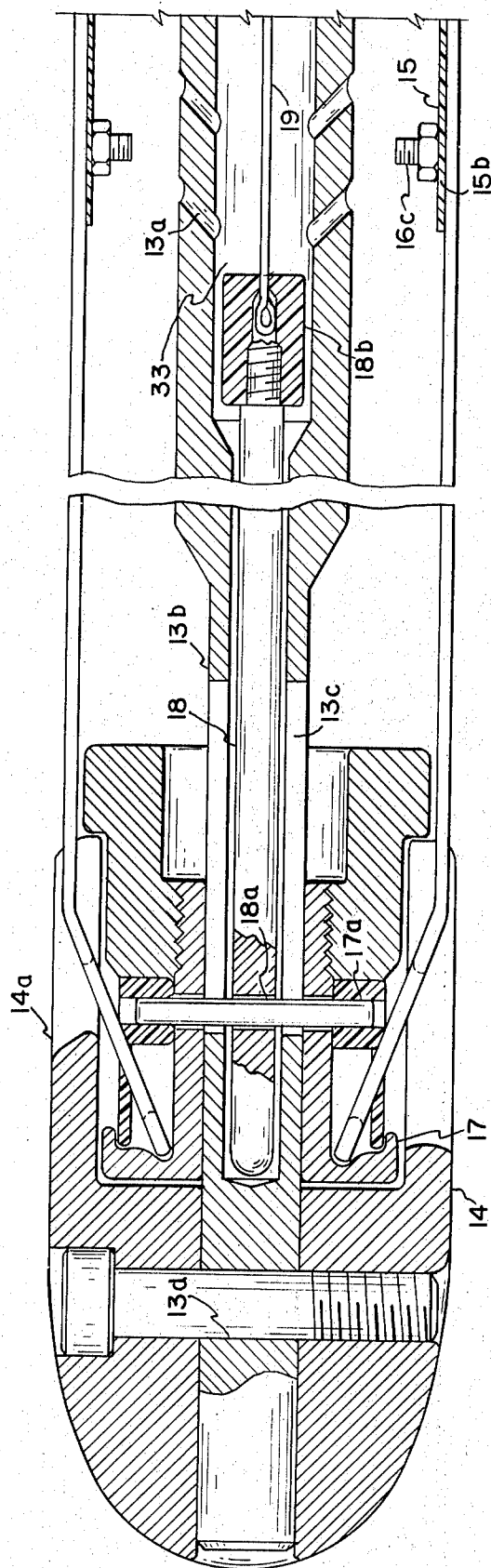


FIG. 2F

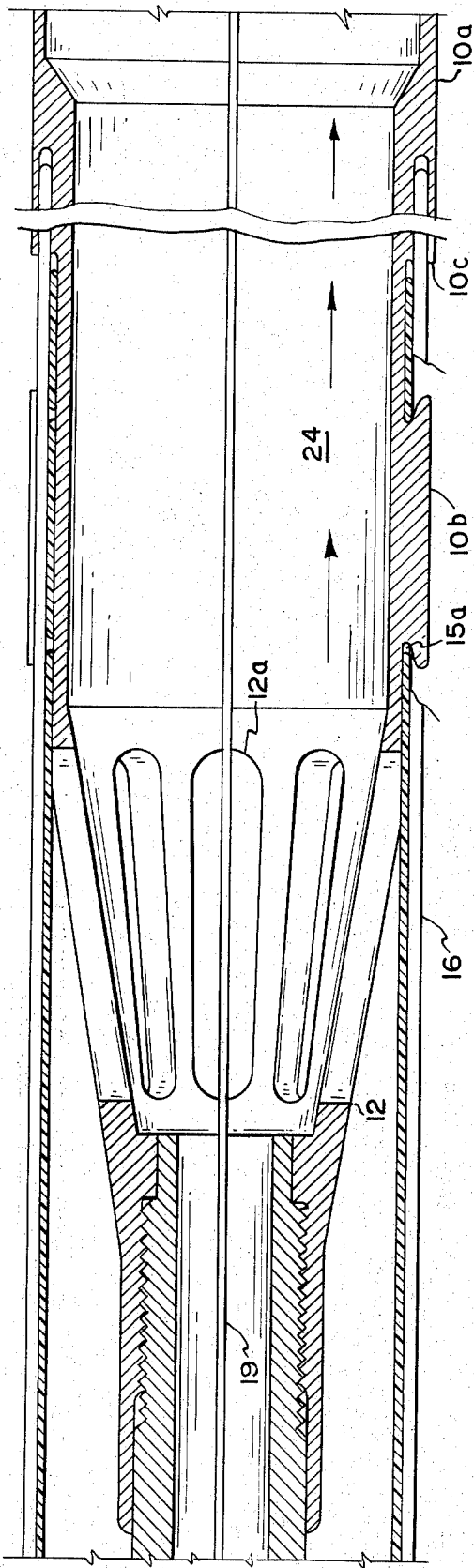
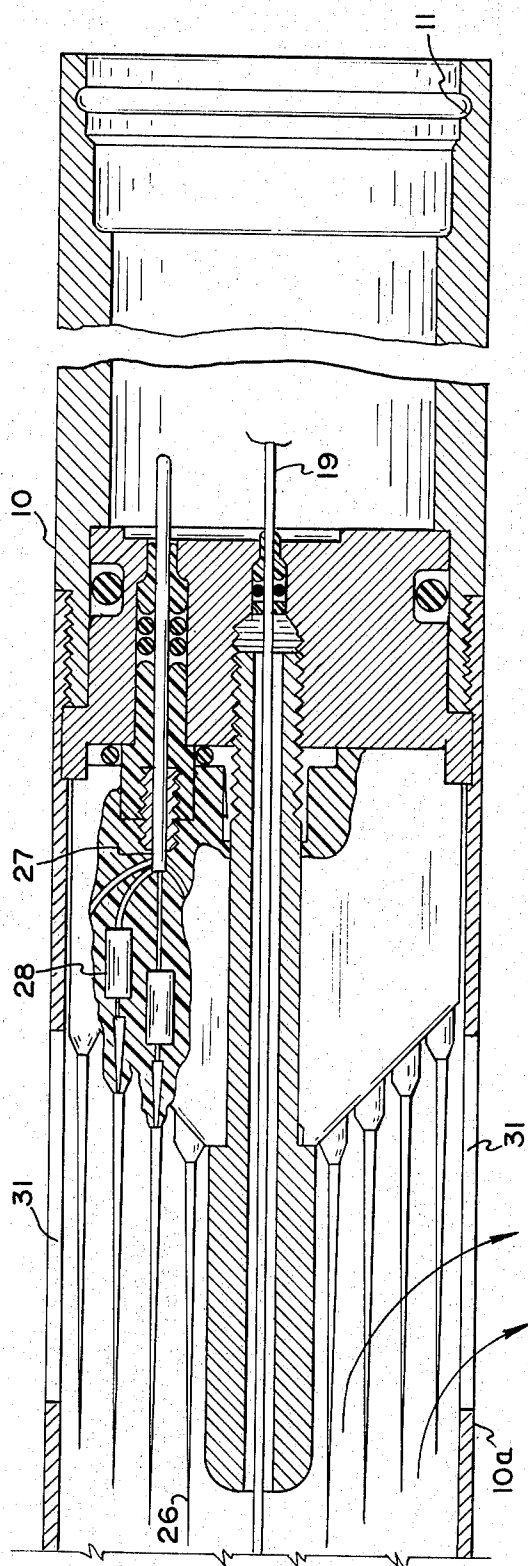
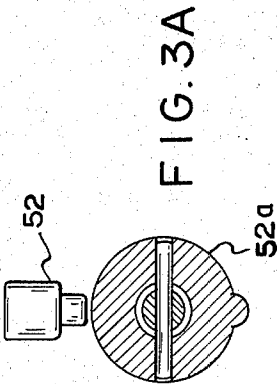
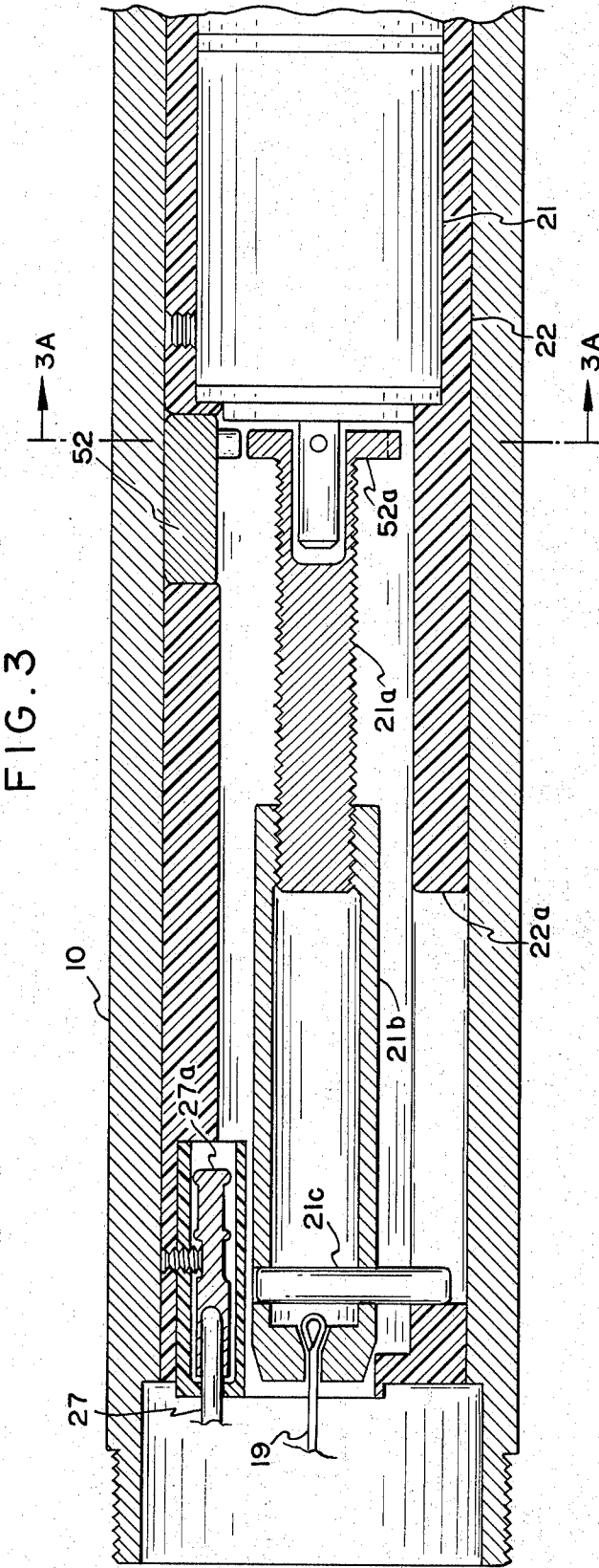


FIG. 2G





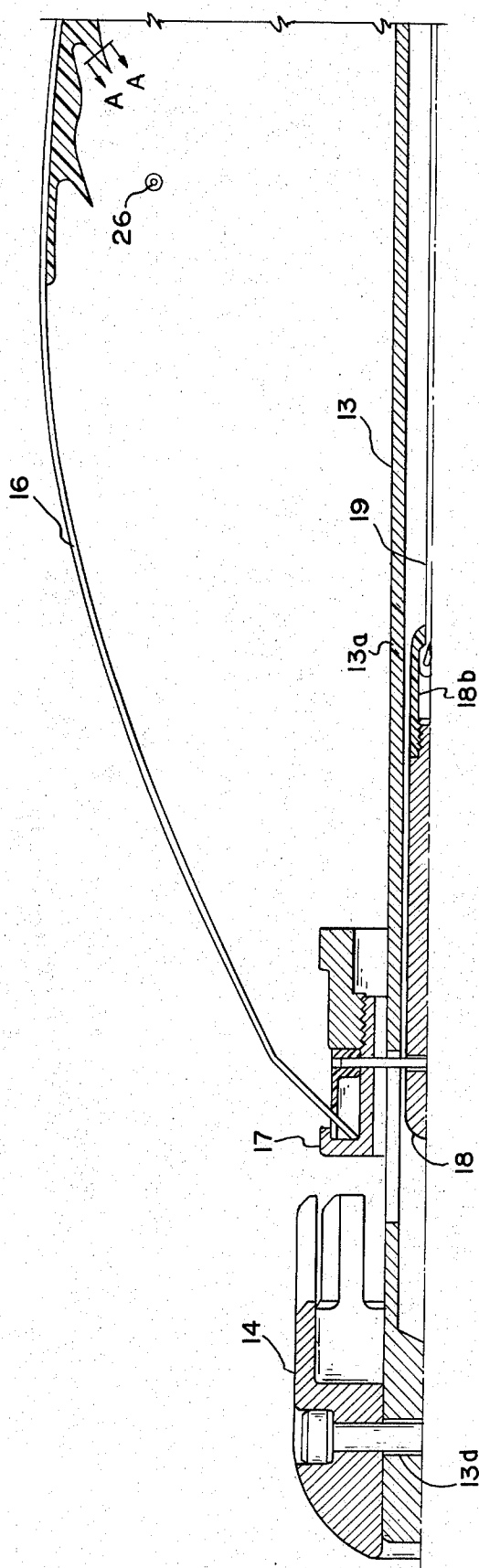


FIG. 4A

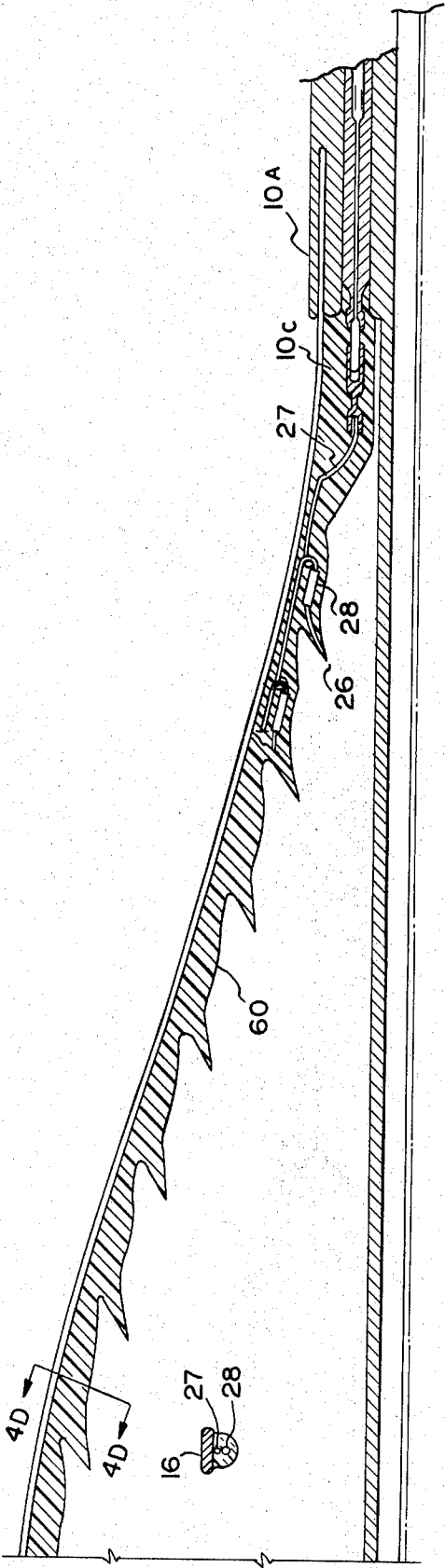
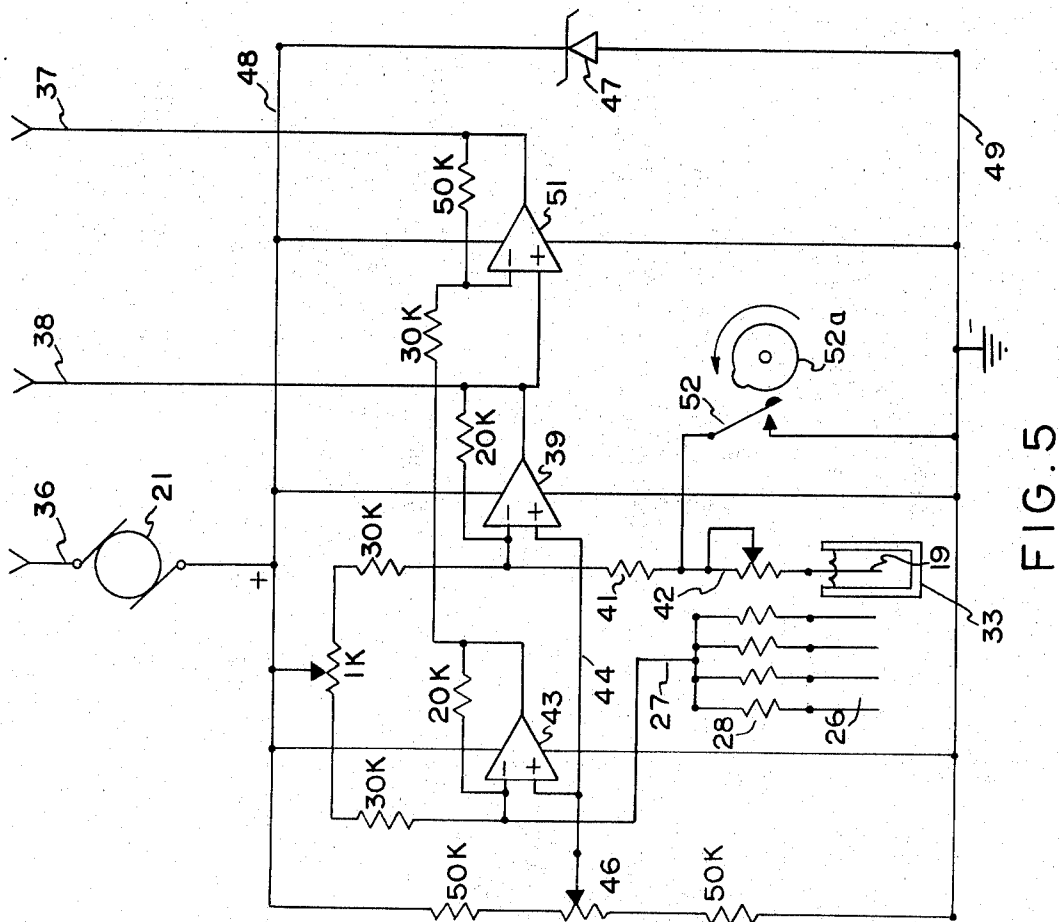
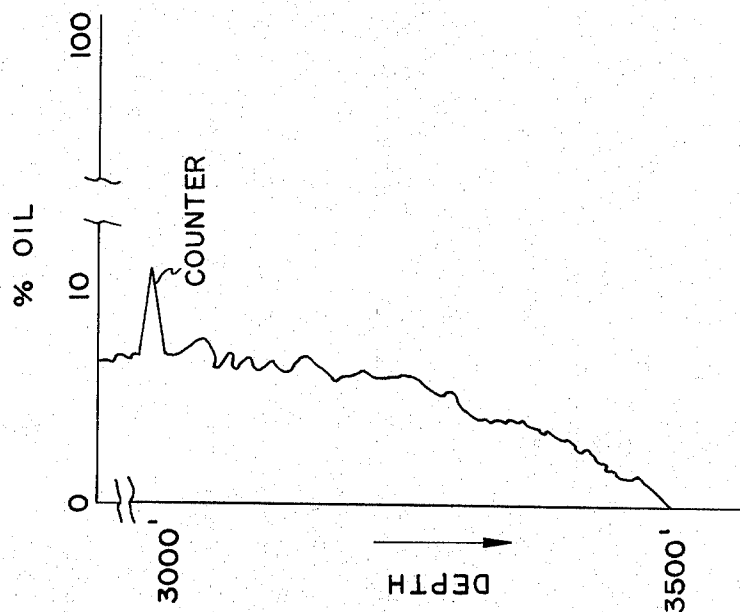


FIG. 4B

FIG. 6



OIL WELL TOOL FOR MEASURING PERCENT OIL

BACKGROUND OF THE INVENTION

The present invention is directed to an oil well tool for measuring the percent of oil in an oil/water mixture in the well.

Prior devices of the foregoing type are usually off-line. For example, the device is lowered into the well, a sample taken, brought to the surface and then analyzed. Another prior art device takes successive samples at various levels in an oil well. Each sample is allowed to settle so that the oil rises to the top. The position of the oil-water interface in the sample tube is electrically measured and at the surface is plotted as a point measurement.

The problem of the foregoing devices is that they take samples at an instantaneous point in space and time and do not provide a continuous record or profile. Concomitantly, of course, their operation is excessively time consuming and is quite limited as to the quality of data, the number of such spot readings being relatively few. Substantial random errors are possible with the spot sample techniques. Experience with the herein disclosed apparatus discloses with a high confidence factor that the percent of oil in water at a given point in the production zone varies with time in many wells. This variation can be such as to produce a reading in a sample three times as great as a sample collected a minute earlier or later.

Another type of device is illustrated by Noik U.S. Pat. No. 3,009,095 which shows a plurality of pairs of electrodes facing each other and in parallel with a spacing of a few tenths of a millimeter. As oil is an insulator, a globule of oil between any of the teeth pair will not cause conduction whereas a globule of water produces conduction. This device, however, admittedly is only for higher oil content of greater than 50 percent.

Where the percent oil content in the well is quite low, for example, less than 10 percent, such well might be approaching its economic margin of operation. Thus, it can be important to obtain an accurate measurement at various levels in the well to provide a profile of the oil/water mixture which may enable remedial measures to be taken to reduce the amount of water; for example, one technique is cementing off the offending water entry. Thus far prior oil tools of the foregoing type have not been sufficiently accurate to provide a reliable profile of the percent of the oil/water mixture.

OBJECTS AND SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a tool that furnishes a continuous profile of the relative concentrations of oil and water throughout the producing portion of an oil well.

It is another object to provide a tool that furnishes a continuous record of the amounts of oil passing a certain point at various times while pumping and other conditions are varied.

It is another object of the invention to provide a tool as above that is capable of making measurements of the oil/water mixture throughout the entire cross-section of an oil well casing.

In accordance with the above objects there is provided a tool for insertion into an oil well for measuring the percentage of oil in an oil and water mixture in the well. Collector means direct the line of flow of at least

a portion of the oil and water mixture. A plurality of electrodes are arranged in a matrix which is substantially coextensive with the cross-section of the flow, each of the electrodes providing an electrical signal in response to the presence of water. Means are provided for summing the electrical signals to provide a statistical analysis of the percentage of oil.

As an alternate to directing the flow a means for adjustably deploying the electrodes in the undisturbed line of flow is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a general overall view of an oil well tool expanded in an oil well liner showing the directed flow embodiment of the present invention;

FIGS. 2E-2F are cross-sectional views taken along the center line of FIG. 1 with the tool in the retracted or slim posture;

FIGS. 2A - 2D are various details which clarify FIG. 2;

FIG. 3 is a cross-sectional view of an extension of FIG. 2G showing the motorized tool deployment means; FIG. 3A is a cross-sectional view taken along the line 3A-3A of FIG. 3;

FIGS. 4A and 4B are cross-sectional view of one half of the deployed electrode embodiment of the present invention shown in the expanded or fully deployed position;

FIG. 5 is an electrical schematic of a circuit used in the present invention; and

FIG. 6 is a profile graph similar to the surface recording but simplified for clarity and usefulness in understanding the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. 1 and 2E - 2G illustrate a cylindrical housing 10 which is adapted to fit into a standard oil well electric line tool string, for example, being coupled at 11 to the string for insertion into the oil well. At the lower end 10a of the housing is a conical entrance port 12 rigidly affixed to 10a and equipped with slots 12a (FIG. 2F) arranged to admit the oil water mixture. Rigidly secured to the lower end of entrance port 12 is a cylindrical tube 13 having a series of slanting perforations 13a (FIG. 2E), a sliding journal section 13b, an elongated slot 13c and securement means 13d for a bullnose 14. The aforementioned assembly of parts 10 through 14 constituting a rigid structure extending the tool string structurally to the bullnose while providing means to support and articulate the following described portions of the present invention.

FIGS. 2A through 2F illustrate an operable and closable fluid directing means which when closed substantially blocks the entrance of fluid into ports 12a (FIG. 2F) but which when open directs substantially all of said fluid into said ports. The fluid directing means consists of a cone 15 fabricated of a durable, resilient, impermeable and nonextensible material such as neoprene-impregnated fiberglass cloth cut to a pattern substantially as illustrated in FIG. 2C. Cone 15 is secured at its upper end by means of projections 10b (FIG. 2F) in the periphery of the lower housing 10a engaging slots 15a in said cone.

The lower or fluid entry end of cone 15 is provided with a row of holes 15b (FIG. 2C) to permit the attachment of said lower end to a spreading means.

The spreading means are composed of a multiplicity of expansible centralizer springs 16 (FIG. 2A) the upper end of which engages lower housing 10a by being inserted into slots 10c (FIG. 2F). The lower end of each centralizer spring is provided with a notch 16a and a toe 16b as illustrated in FIG. 2B.

The notch prevents the escape of the spring from the articulating means at its lower end and the toe prevents the upper end of said spring from escaping from slot 10c at its upper end.

A cage assembly 17 slidably journaled to 13b provides the articulating means whereby the centralizer springs 16 are expanded as shown in FIG. 1. The cage assembly causes the expansion of the centralizer springs by its upward motion along the journal section 13b of tube 13. The upward force is conveyed to cage assembly 17 by cross pin 17a which pin is free to travel in slot 13c. Cross pin 17a passes through hole 18a in drawbar 18 and by means of insulating cap 18b the drawbar is attached to conductive piano type wire 19. FIG. 3 shows the upper end of wire 19 arranged to be pulled by a gearhead motor 21 by means of a screw 21a affixed to the motor shaft and a nut 21b affixed to said wire 19. To facilitate an electrical connection to conductive piano type wire 19 for its function as a reference electrode both motor 21 and lead screw assembly 21a and 21b are insulated from ground by insulating sleeve 22 which also bears a slot 22a to engage pin 21c to prevent nut 21b from turning. Insulating sleeve 22 also bears a turns counter 52 and a receptacle 27a to permit electrical connection to the later described electrode assembly. It must be understood that the feed-through seals and bushings for both the wire 19 and the sensor common point 27 are of a suitable insulating material.

It is apparent that the pulling of wire 19 by motor assembly 21 will lift cage 17 and expand springs 16. This action opens cone 15 whose lower edge is secured to a suitable point along each spring by means of studs 16c (FIG. 2E) affixed to the springs engaging holes 15b located around the skirt of cone 15. The closing force to return the tool to a slim posture and maintain a proper tension on wire 19 is by means of springs 16 which have a suitable preformed shape to provide the appropriate force over the active distance.

The prime purpose in closing the tool is to permit its safe passage around the pump and/or through the relatively slim strings of observation tubing above the zone of measurement interest. However, as will be explained below, the degree of opening of the cone 15 can be controlled so that the cross-section of the oil/water mixture in the well which is brought into the tool itself can be varied as desired. This flow is brought through the inlets 12a into the casing portion 24 into contact with a plurality of electrodes 26 (FIG. 2G). These electrodes are needle shaped and parallel to each other and the oil flow as illustrated by the arrows. A cross-section of the needle electrodes is illustrated in FIG. 2D. As shown in FIG. 2G, all the electrodes are connected to a common point 27 through resistors 28. Each of the resistors 28 has a resistance, for example, 4.7 megohms, which is much greater than nominal resistance of the water in the well. This nominal resistance may be as low as a few ohms due to normal salinity of the water in the oil well or it may rise to a few hundred ohms depending on unusual local conditions. In any case, this variation of resistance is, in effect, nullified by the very

large series resistances of the resistors 28. The oil/water mixture after contacting the electrodes 26 exits through the ring of ports 31. Along the tube 13 as illustrated in FIG. 2E there is provided a water collector 33 having slanted apertures 13a. Because of the fact that as the tool is being lowered in an oil well to provide a profile chart of the oil/water mixture the oil will rise faster than water, the cavity 33 will contain only the water present in the locale of the well. Since the piano wire 19 is conductive, this provides a reference electrode which, as will be discussed in conjunction with the circuit of FIG. 5, provides a reference voltage which compensates for offset voltages which may be present in the oil well. These offset voltages are due to the electrolytic effects and may create voltages of as much as one volt.

As illustrated in FIG. 2D, the electrodes 26 in essence provide a matrix which is coextensive with the cross-section of oil/water flow. This, thus, in effect provides a statistical analysis or assay for the amount of oil in the oil/water mixture. The sensing points are typically arranged so that each point is at the center of an equal portion of the cross-section of flow. For other purposes they may be irregularly deployed, for example, more dense near the center to make statistically weighted measurements.

In general, in operation where one of the sensing electrodes 26 is contacting water, it will conduct electric current to ground; where it is immersed in a globule of oil it conducts no electricity. In the preferred embodiment the electrodes have only their tips exposed with the remainder of the needle being coated with a plastic insulator. The needles 26 spear oil globules in the flow path without diverting them, so that each sensing point provides a continuous digital indication of the presence or absence of oil at a precise point of cross-section of flow. This conduction of electricity to ground is, of course, possible since for higher water contents, for example, above 50 percent, the water generally forms the continuous phase of the oil/water mixture.

Thus, by lowering the tool in an oil well with the cone extended to the proper diameter, for example, that of the oil well casing, a profile of the percent oil in a well as illustrated in FIG. 6 may be obtained. This may be used to determine the appropriate remedial measures for improving the percentage of oil in the well.

FIG. 5 illustrates the circuit for providing the profile voltage of FIG. 6 and is contained in the same cavity as the motor 21 in the tool. Three electrical wires extend down the well one of which, 36, supplies a positive dc voltage; a second, 37, indicates the summed electrical signal from the electrodes 26, and line 38 provides a reference voltage to compensate for offset voltages in the oil well.

More specifically, such reference voltage is obtained as discussed from the cavity 33 in tube 13 which contains the conductive piano wire 19. This is coupled into a reference amplifier 39 through resistors 41 and 42 which are nominally at values of 50K ohms each. Resistor 42 is adjustable. The common point 27 of the electrodes 26 is coupled into a signal amplifier 43. Both reference and signal amplifiers 39 and 43, respectively, have their outputs coupled back to their inputs by 20K ohms resistors. In addition, each of these amplifiers is provided a reference voltage on line 44 which is nomi-

nally 11 volts and may be adjusted by the scale adjustment potentiometer 46.

The operating voltage on line 48 for the circuit is derived through the motor 21 from the dc voltage line 36. This voltage is maintained at a nominal 22 volts by Zener diode 47 during either operating or nonoperating conditions of motor 21. The motor, of course, operates at a certain threshold current and when the current is reduced below this point even though the motor is stationary the voltage will still be provided on the line 48. Line 49 is ground. This voltage supply also supplies the output amplifier 51 which is coupled to the signal line 37.

A turns counter 52, indicated as a switch, counts the revolutions of motor 21 to indicate the extent of opening of the flexible cone of the tool. The counter closes once every revolution and produces a voltage pulse on reference line 38 illustrated in FIG. 6. Thus, the user by counting such pulses can determine the extent of the opening of the flexible cone. No oil/water measurements are made during the cone opening period and switch 52 is left open for proper measurement operation.

The reference voltage is adjusted by means of the potentiometer 42 which is adjusted to provide a zero signal voltage relative to the reference voltage when all the electrodes 26 as well as the reference electrode 19 are coupled together and grounded in a water bath. This in essence is the same as a measurement in a well where the well is all conductive water; i.e., zero oil.

The remaining resistors of the circuit are given nominal resistive values in ohms. The circuit of FIG. 5 applies a voltage at the common point 27 from the positive voltage line 48 which may be of the range of 10 to 15 volts. Since this voltage is much greater than the offset voltages (0 to 1 volts) which may be present, error due to such offset voltage will be minimized. This is true even if the water reference probe, 12, 19, 33 is not utilized.

The positive voltage on line 48 also provides a positive voltage to the electrode 26 to avoid any plating on effect to the electrodes which would occur with a negative voltage. This keeps them relatively clean to provide for accurate measurement. It should be pointed out, however, that this invention has operated quite successfully using a negative potential on the electrode.

As stated previously, the present invention is ideal for measuring percent of water in an oil/water mixture where the water is predominant. If it is desired to measure a mixture where the oil is predominant, in other words, in the continuous phase, the electrodes 26 can each be made in a coaxial format with a spacing between the inner conductive portion of the needle and a grounded outer conductive portion so that globules of water will cause conduction.

Another embodiment of the invention utilizes the same basic circuitry and statistical sampling approach as well as the same water resistance and galvanic offset voltage compensation method as heretofore described and it could be adapted to operate where the water is not the continuous phase by associating each sensor point with a proximitous grounded region. This embodiment is not given second place in this application for lack of preferment but rather for clarity. Neither should the brief space allotted to the description be interpreted as other than evidence that much of the foregoing description applies to both embodiments.

DETAILED DESCRIPTION OF THE DEPLOYED SENSOR EMBODIMENT

This embodiment of the invention is illustrated in FIGS. 4A and 4B only. It must be understood that where applicable the details of other figures are to be consulted. Corresponding details use the same detail numbers to permit ready comprehension when related to the portions of the foregoing description common to both embodiments.

Under certain circumstances it is desirable to monitor well conditions while minimizing the disturbance to the flow and under other circumstances such as roughly textured liner interiors it is difficult to direct a suitably representative flow. For these and other reasons the previously described structure is modified to deploy the sensor points 26 by embedding the resistors 28 in an elastomeric insulating matrix 60 such as synthetic rubber or polyurethane the matrix being bonded to the inner side of a multiplicity of centralizer springs 16 adapted to be expanded as previously described.

The spacing along the inner side of the springs as well as the number of springs is appropriate to the conditions at hand. The object is to intercept a typical line of flow in the well for most accurate analysis. Summing point 27 on the one spring shown is connected to all other points 27 on the companion springs.

Thus, the present invention as described above provides an improved tool for measuring the percentage of oil in an oil/water mixture which provides a statistical analysis of the quality of such mixture in an easy to interpret profile form. It is very accurate with relatively high percentages of water in the mixture. Errors are eliminated due to both changes in resistance because of variations in salinity and also due to galvanic offset voltages in the well. The mode of operation permits wide variations in physical design to suit specific well conditions and the electrical arrangements for reporting measurements to the surface are easily customized to existing surface instruments as long as the summing function is properly implemented.

I claim:

1. A tool for insertion into an oil well for measuring the percentage of oil in an oil and water mixture in the well comprising: a plurality of electrodes arranged in a matrix which is substantially coextensive with the cross-section of the flow of said mixture, said mixture containing a relatively low percentage of oil so that said water is in a continuous phase and said oil forms globules, means providing electrical signals in response to the presence of water at each electrode and no signals at the electrodes which are surrounded by an oil globule; and means for summing all of said electrical signals to provide a statistical analysis of the percentage of oil.

2. A tool as in claim 1 where said summing means includes a plurality of resistors respectively series coupled between each of said electrodes and a summing point, each of said resistors having a resistance value much greater than the nominal resistance of water in said oil and water mixture.

3. A tool as in claim 1 including means for collecting only water in proximity to said matrix and including reference electrode means immersed in such collected water for providing a reference for the sum of said electrical signals whereby offset voltages in said oil well are compensated.

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4. A tool as in claim 2 including means for applying a voltage signal to said summing point which is much greater than offset voltages in said oil well.

5. A tool as in claim 4 where said voltage signal is positive d.c.

6. A tool as in claim 4 where said voltage signal is negative d.c.

7. A tool as in claim 1 including collector means for

directing the line of flow of at least a portion of the oil and water mixture into a flow pattern substantially co-extensive with the electrodes.

8. A tool as in claim 1 including means for deploying the electrodes in a pattern substantially coextensive with the undisturbed natural flow in the well.

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