May 6, 1952 D. SILVERMAN ET AL 2,595,610

FLUID INGRESS LOCATION IN WELLS

Filed Dec. 30, 1949 3 Sheets-Sheet 1

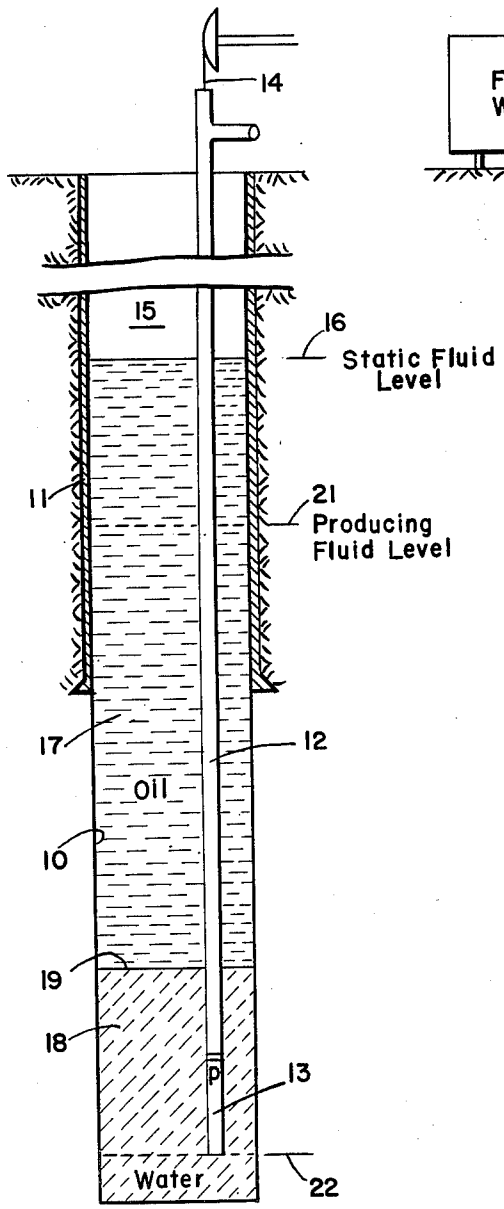


Fig. 1

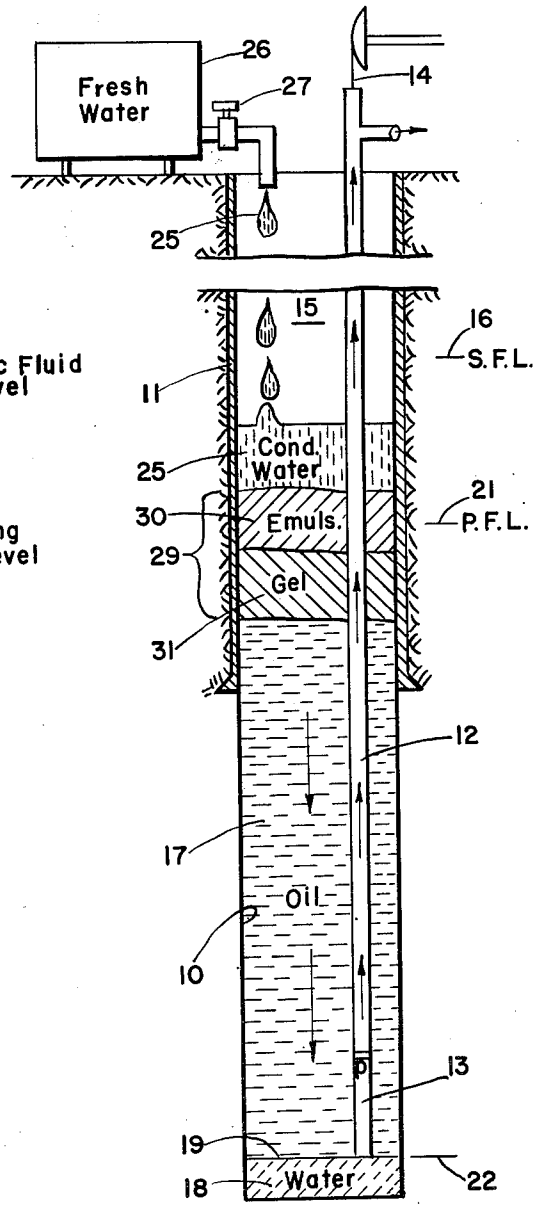


Fig.2

Fluid Legend: Oil, Cond. Water, Well Water

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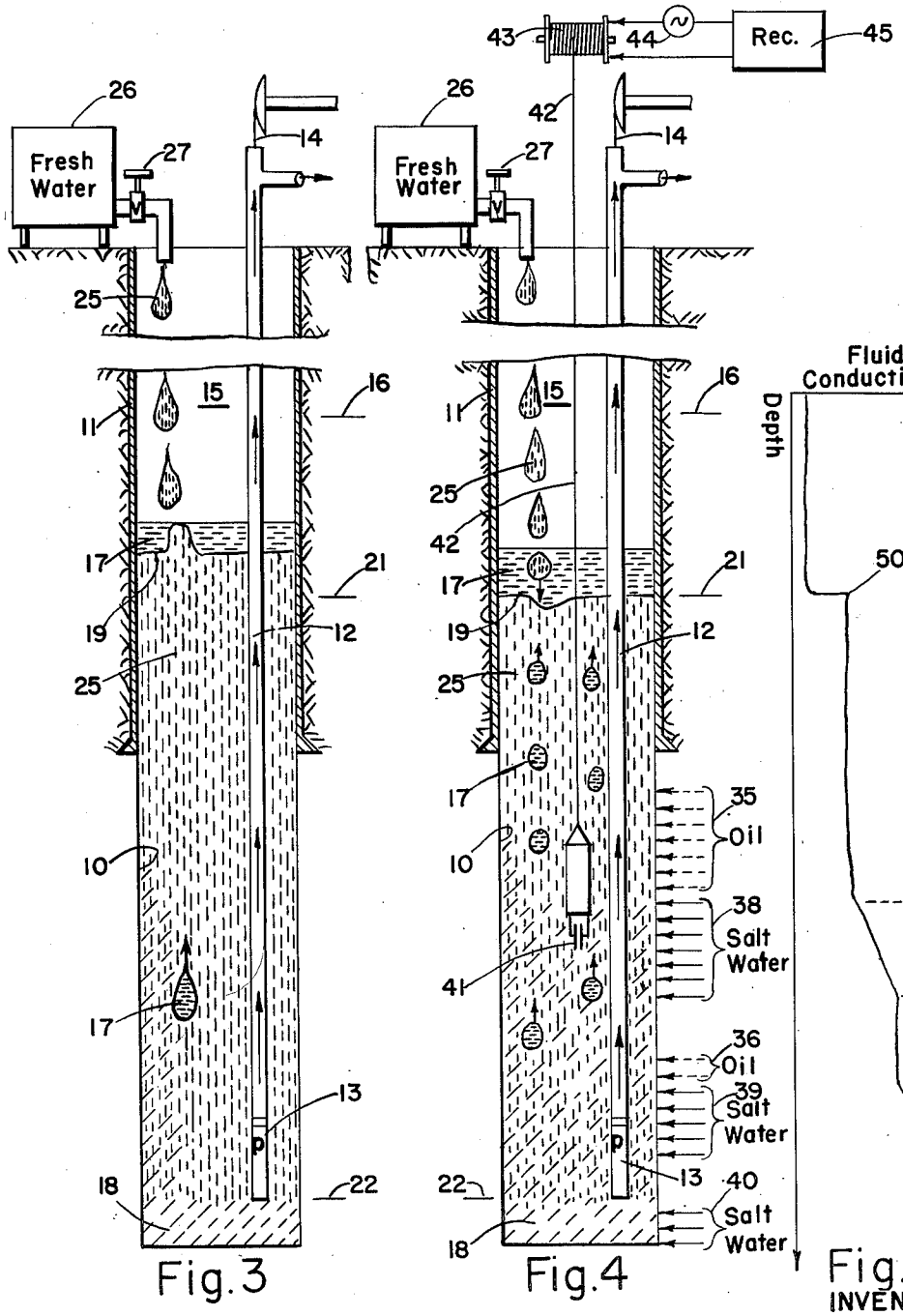


Fig.5

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Filed Dec. 30, 1949 3 Sheets-Sheet 3

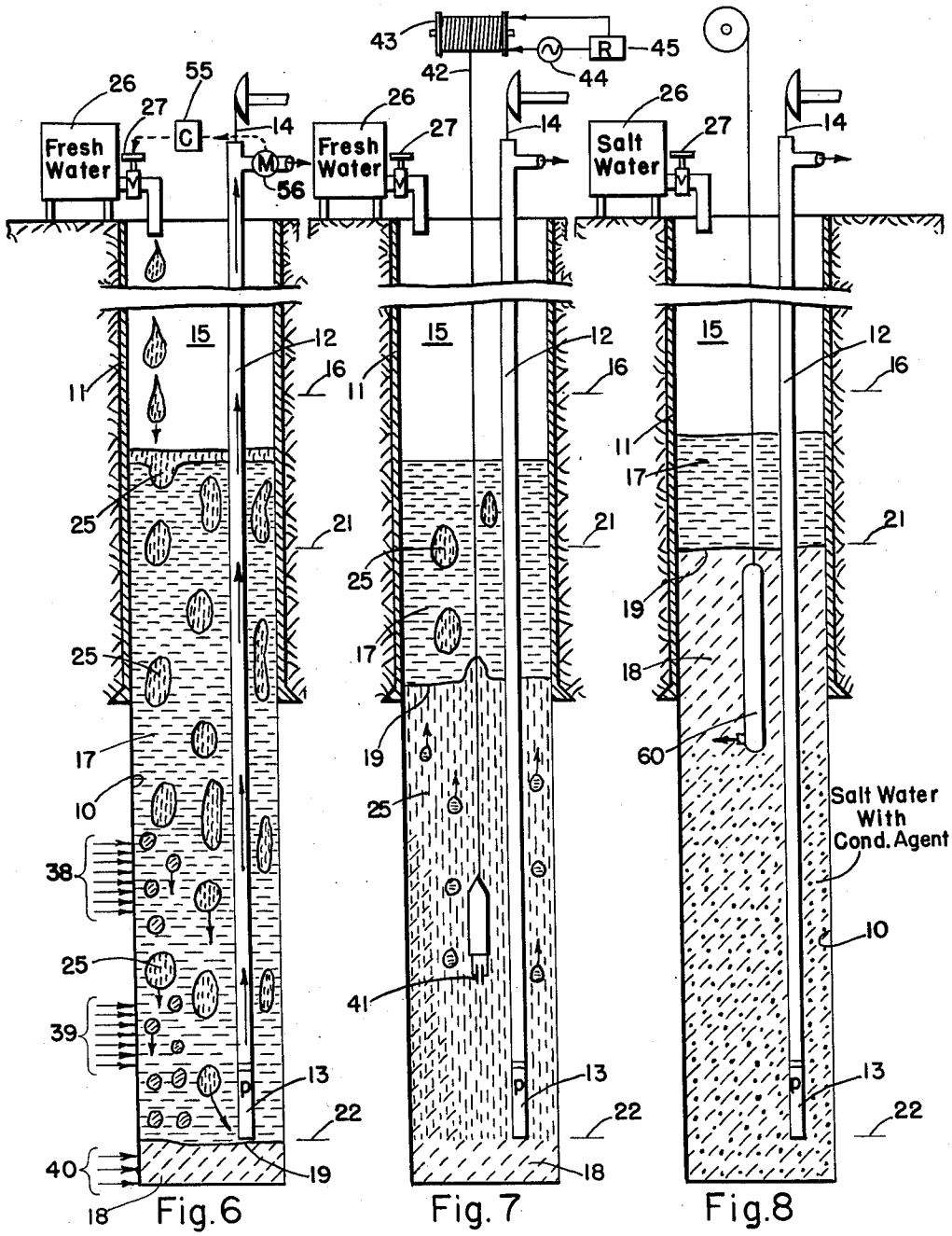


Fig. 6 Fig. 7 Fig. 8

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FLUID INGRESS LOCATION IN WELLS

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17 Claims. (Cl. 171—182)

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This invention relates to testing wells and is directed particularly to determining the location of ingress of well fluids, particularly in wells producing a plurality of such fluids, such as oil and gas wells which also produce water. As problems of fluid-entry location arise most frequently in connection with oil and gas wells which produce undesired water or brine along with the desired hydrocarbon fluids, the invention will be described with reference to such wells, although its utility is clearly not of such limited extent.

Numerous attempts have been made, and some commercial success has been attained in solving problems of fluid-entry location in oil and gas wells, but all of the methods heretofore employed have had their utility somewhat limited by certain difficulties and drawbacks. Almost all of such methods have employed well-conditioning or preparation steps which have required extended periods of time and very careful manipulation of the well or of the conditioning fluids and well equipment. To avoid over-balancing the natural fluid pressures of the exposed well formations, thus forcing into them foreign fluids which might later mask the identity of the true formation fluids, extreme and often impractical precautions have been necessary. Frequently, the success or the failure of a well-testing process has been dependent upon the manner of distribution of a particular testing material through the well or the well fluids, such material being also more or less expensive and hazardous to handle in the case of radioactive tracing agents and solutions. In addition, with some testing methods, the significant indications are of such short duration that they could be completely missed, if the measuring or detecting equipment happened to be at a different level in the well at the critical time. In most of such prior art methods also, the tests are carried out with the well under quite different producing conditions from those which may prevail during the normal production of the desired oil and gas from the well. Also a drawback in some cases is the fact that the insertion of additional tubing into the well, or more or less handling of the well equipment may be required, all of which add very greatly to the time and expense of the testing operation.

In view of the fact that in our invention most of the foregoing disadvantages and drawbacks are minimized or completely absent, some of the objects of our improved testing procedure for wells may be briefly enumerated as follows: (1) to provide a well-conditioning procedure of simple nature, capable of being carried out from the

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ground surface, with a minimum of interference with the normal producing of the well; (2) to provide a conditioning procedure having no possibility of overbalancing the static fluid pressures in the permeable formations and causing intrusion of foreign fluids into them; (3) to employ inexpensive and non-hazardous conditioning agents; (4) to produce in a well a semi-permanent indication or pattern which is capable of being repeatedly observed as long as or as often as desired, which pattern is readily and simply interpretable; (5) to employ very simple testing and recording equipment; (6) to carry out the testing with very little or no handling or modifications of the well-producing equipment; (7) to obtain the significant indications with the well either at or close to the producing equilibrium condition which prevails during normal fluid production; and (8) to control the producing conditions of the well during the testing steps at will from the surface. Other and further objects, uses, and advantages of the invention will become apparent as the description proceeds.

We accomplish the foregoing and other objects by a method of well testing which involves, generally, first lowering and then in subsequent steps maintaining the bottom-hole pressure in the well below static, that is, below the bottom-hole pressure which exists when the well is shut in and all production has stopped; placing a column of conditioning liquid throughout the well test zone, which ordinarily means replacing the formation fluids which accumulate there; flowing the conditioning liquid column through the test zone and past the producing formations, while formation fluids enter and contaminate or dilute the conditioning liquid at their locations of ingress (due to the below-static bottom-hole pressure); and measuring the pattern of contamination as a function of depth.

By maintaining the bottom-hole pressure always below static, for example, by pumping the well more or less continuously, at least two very important advantages are gained: there is never any possibility of intrusion of the conditioning liquid into the well formations, and the formations are always producing their natural fluids into the well bore. The testing is carried out with the formations producing at any desired rate, even approaching that occurring during normal fluid production.

There are several ways of placing the conditioning liquid throughout the well test zone, each having advantages in certain situations. It is even possible to utilize the well fluids themselves

after appropriate addition of a conditioning agent which will be affected by the entry of further well fluids as the conditioned liquid flows by the producing formations.

This will be better understood by reference to the accompanying drawings forming a part of this application, taken with the following detailed description. In these drawings, in which the same reference numerals are applied to the same or corresponding parts in the different figures:

Figures 1 to 4, inclusive, show in cross section a typical well and the fluid conditions therein before and during certain steps of the performance of one modification of the testing process of our invention;

Figure 5 is a log of the fluid conductivity obtained as a function of depth in the well;

Figures 6 and 7 show the fluid conditions in a well during conditioning by the procedure forming a preferred embodiment of the invention; and

Figure 8 shows an embodiment of the invention utilizing treated well fluids as the conditioning liquid.

Referring now to these drawings, and to Figure 1 in particular, a well 10 is shown diagrammatically in cross section as equipped with a casing 11 and a tubing string 12 through which the well is produced from a point near the bottom by a conventional pump 13 operated, for example, by a sucker rod string 14. If the inlet to pump 13 is not normally near the bottom of the well, or at least below the zone to be tested, it is placed there prior to the beginning of the testing process of the invention.

If well 10 is shut in for a period of time so that a state of equilibrium is reached, the well fluids in the annulus 15 between casing 11 and tubing 12 rise to a top level 16, designated as the "static fluid level," the fluid column then comprising an upper body 17 of oil and a lower body 18 of salt water separated by a sharp interface 19.

When well 10 is in a state of producing or dynamic equilibrium, with fluid being removed by pump 13 through tubing 12, the fluid conditions are as indicated by the dashed lines, with the top of oil 17 at the producing fluid level 21 and the interface 19 between the oil 17 and salt water 18 at the level 22 of the inlet to pump 13 where it is shown in Figure 2. The difference in bottom-hole pressure, between the condition with the well fluids at the static level 16 on the one hand and at the producing level 21 on the other hand, is that reduction in bottom-hole pressure required to cause the fluids to flow from the surrounding formations into the well at the rate determined by the rate of operation of pump 13 in lifting these fluids from the well 10. For the purposes of this invention, it is desirable but not essential to know within approximate limits what these two pressures are, or at least the pressure difference, as it is one of the important features of the invention that all of the conditioning and testing steps are carried with the bottom-hole pressure below static—in other words, at a pressure level below that when the well is in static equilibrium. The procedures to be described have proven useful in substantially all wells tested, but are especially useful in wells where the pressure difference between static and producing equilibrium is small, which wells are difficult to condition by other methods.

Referring now to Figure 2, the well 10 is shown in a stage of the preliminary conditioning which precedes the measurements for determining the locations of ingress of the salt water. In accordance with our invention, as much as possible of the oil body 17 is removed from the annulus 15 by producing or pumping it out through the tubing 12, while introducing fresh water 25 from a surface tank or source 26 into the annulus 15 at a rate, determined by a control valve 27, which is a substantial fraction of but does not exceed the pumping rate. If fresh water 25 is simply introduced alone into annulus 15 on top of oil column 17, the bottom-hole pressure having first been reduced by pumping, a certain amount of mixing and overturning occurs, with globules of water falling through the oil, due to the different specific gravities and the immiscibility of the two fluids.

This mixing of the oil and water does not ordinarily prevent satisfactorily conditioning the well, however, since the rate of falling of the water in globules through the oil 17 is low. Velocities of fall ranging from four to ten feet per minute have been observed in a number of wells. By continuing to pump while the water 25 moves slowly downward in globules, a substantial portion of the oil column can be removed to make space for the necessary conditioning water column to extend through the well test zone, without ever exceeding the static bottom-hole pressure.

When it is desired, however, to minimize the intermixing of the oil 17 and water 25, so as to displace the oil from the annulus 15 with the greatest possible effectiveness, a deformable separating plug 29 of pumpable viscous liquid or gel is interposed between the oil 17 and the following fresh water 25 to resist their tendency to mix and overturn. The plug 29 readily adapts itself to changes in shape of the annulus 15, passing tubing and casing joints and the like in a manner that would be impossible if it were a solid body rather than a highly deformable liquid or gel.

Suitable materials for forming plug 29 are, for example, a stiff emulsion of oil and water 30 or a water- or oil-base gel 31. A suitable oil-base gel can be formed by adding a thickening agent such as "Napalm" to crude or refined oil, or a water-base gel may comprise water plus bentonite or hydrolyzed starch. The separating plug material 29 may comprise any of these materials, alone or in combination in the form of two or several layers. For example, it may be desirable to employ a water-in-oil emulsion 30 in contact with the water 25 and the oil-base gel 31 in contact with the oil 17 to prevent contact of the water 25 with the gel 31 which might cause breaking of the gel.

With the well in the condition shown in Figure 2, pump 13 is removing the oil column and a minor amount of production from the well formations through the tubing 12 to the surface, while water 25 is being introduced from supply 26 through valve 27 at a rate which is only slightly less than the rate of pumping through the tubing measured on a weight basis which is the intended basis of measurement or comparison throughout this specification, unless otherwise indicated. The introduction of the plug 29 and water 25 may be started just as soon as the bottom-hole pressure has been reduced below static by pumping, but it is preferably begun with the well near or at the producing equilibrium level 21. The important limitation is that the rate of introduction of plug 29 and water 25 shall never exceed the rate of pumping of the well through tubing 12, so that as a result the bottom-hole pressure in well 10, after the initial reduction, never can return to or exceed the static value. Consequently, none of the fluids in the annulus 15 can enter these

formations; and finally the conditions shown in Figure 3 are reached, after a period of time, in which substantially the entire fluid column in annulus 15 is fresh water 25, with the oil 17 having been produced through tubing 12, together with the gel 31 and the emulsion 30. A small amount of oil 17 may still exist on top of the water column 25 due to some by-passing of the plug 29 and to the minor amount of oil produced by the well formations during placement of the water column 25 under the reduced bottom-hole pressure. Some globules 17 of this produced oil are shown moving upward through the water 25 in this figure. This oil may generally be disregarded, however, because subsequently introduced water 25 readily falls past or through it to join the main water column, and its contribution to the bottom-hole pressure remains relatively constant.

The well 10 is now ready for the fluid measurement step of the process illustrated in Figure 4, to obtain the fluid conductivity log of Figure 5. It will be assumed that the formations penetrated by well 10 produce oil over the two intervals 35 and 36 and salt water from the three zones 38, 39, and 40. A pair of fluid-conductivity electrodes 41 is lowered into the annulus 15 on an insulated-conductor cable 42 carried on a reel 43 at the surface at the top of well 10, suitable leads and slip rings connecting electrodes 41 through the cable on reel 43 to a current source 44 and an indicator or recorder 45.

Pump 13 is operated to lift fluids at a normal rate ("normal" is here used in the sense that the pump stroke rate and length are the same as in the usual producing of well 10), or at any other preferred rate greater or less than normal, to draw down the column of water 25 and simultaneously induce oil and salt-water production from the formations into the well bore and water column 25. Additional water 25 from the surface supply 26 is introduced at some fraction of the pumping rate, and this constitutes the control of the well-formation producing rate. After any period of steady pumping and constant-rate water addition to annulus 15 from the surface, a producing equilibrium is reached where the rate of water addition plus the rate of fluid entry from the well formations equals the pumping rate. Thus by making the water addition rate large or small, the formation producing rate will be conversely small or large, and it is a simple matter to regulate it to any value desired.

With the producing, pumping, and water introduction conditions established, the rate of entry of salt water at each of zones 38, 39, and 40 and the rate of downward movement of water 25 are constant, and the pattern of contamination or dilution of the fluid column is a steady or semi-permanent one. It is only necessary to traverse the electrodes 41 through the annulus 15 and record the fluid conductivity as a function of depth on recorder 45 to obtain the log of Figure 5.

In this figure the top of the main water column produces the conductivity increase at 50, the salt-water stratum 38 produces the gradual conductivity increase 51, salt-water stratum 39 produces the second gradual increase 52, and the sudden increase to the final high value of conductivity 53 indicates the location of pump inlet level 22, below which there is almost always undiluted salt water. Since this salt water generally cannot be displaced by fresh water 25, the existence of the bottom salt-water entry 40 is ascertained at the end of the drawdown by the build-up step in which pump 13 is stopped, and valve 27 is closed. Well 10 continues to produce, raising the fluid level toward static, and the fluid entering from stratum 40 causes the high-conductivity indication 53 to appear to move upward, as observed by the electrodes 41, proving the existence of the bottom fluid entry.

It is of course not necessary always to make the log of Figure 5 with the well at any specific producing equilibrium, as the main features of the log and the zones of entry become apparent very early in the drawdown, as the step of flowing the conditioning water through the test zone is termed. Beginning with the bottom-hole pressure just under static, if no water is added to annulus 15 while pump 13 is operated steadily, the well formations produce at an increasing rate, and water column 25 flows downwardly at a decreasing rate, until the normal producing equilibrium condition is reached. By repeatedly traversing electrodes 41 through the fluid column, logs are obtained of the contamination pattern for a whole series of different formation-fluid production rates.

In steady-state testing only one traverse of electrodes 41 is required to obtain the log of Figure 5. In actual practice, however, the electrodes are traversed repeatedly until it is seen that a steady-state condition has been reached by the fact that the log being obtained is repeated. Then the build-up step mentioned above to check bottom fluid production may be started.

In Figure 6 is illustrated another and preferred way of carrying out the testing of our invention, without the substantially complete preliminary displacing of the oil column illustrated in Figures 2 and 3. Thus the fresh water 25 from tank 26 is introduced at a steady rate which is a substantial fraction, such as from 50% to 75%, of the well pumping rate, over a period of time while the well is pumped steadily by pump 13 through tubing 12. This operation should continue at least until the first water 25 introduced has fallen through the oil column 17 and reached the well bottom, as in this way the maximum amount of oil 17 is displaced by the water. With a rate of fall between four and ten feet per minute and, say, a 3,000-foot column of oil, at least five hours is required; and during this period the principal fluid lifted by the pump 13 is the oil 17 from the annulus fluid column, as production from the formations is held back by the increased bottom-hole pressure of the added water 25. This large amount of water can be introduced and will ultimately be available for testing purposes without the bottom-hole pressure ever exceeding static.

The water addition can be and preferably is continued somewhat longer than is required for it to reach bottom, in order to purge the well of salt accumulations which otherwise would initially contaminate the fresh water 25 and reduce its conductivity contrast with the well water entering during the subsequent drawdown step.

A particularly advantageous way of carrying out this continuous water addition is to arrange for an interlocking control 55 between the tubing outlet and the water inlet valve 27, for example, by actuating a control mechanism from a meter 56 through which the pump production passes, such that the water input rate is the desired predetermined fraction of the well output. This water circulation step is then allowed to operate continuously, and unattended if desired, for several hours, preferably overnight. If by chance the pump 13 stops, the interlocking control 55

immediately and automatically shuts off the introduction of water 25 to prevent flooding of the well formations.

At the time and after water 25 reaches the well bottom, where it is picked up by pump 13 and returned to the surface, a producing equilibrium condition is established in which the pumping, formation fluid production, and downward conditioning water flow rates are all substantially constant. The conductivity electrodes 41 could be run in at this time and the contamination of the descending fresh water 25 by the formation water measured to produce a log as in Figure 5; but in order to avoid the interference of oil blanketing the electrodes it is preferred to stop the pumping and water addition temporarily and let the water 25 form a consolidated column extending at least through the well test zone.

This is shown in Figure 7, and when it is found by surveying with electrodes 41 that the consolidated water column 25 is of sufficient height to supply the contemplated drawdown, the pumping, and water addition if desired, are resumed. The contamination pattern presently appears, and a log with the indications 51, 52, and 53 (Figure 5) is obtained by traversing the electrodes 41 up and down the well annulus. The control of the operation by water addition from the surface is the same as was described in connection with Figure 4, and the same procedure of stopping pumping and water addition at the end of the drawdown step to permit a build-up of fluids in the well annulus for indicating bottom fluid entry can be used.

In the event fresh water 25 is not conveniently available at the well location, the well water itself, after addition of a suitable chemical agent, can serve as the conditioning liquid. For example, by adding a small amount of sulfuric acid to the well water and making electrodes 41 of dissimilar metals a voltaic cell can be formed which is sensitive to dilution by entering well water to vary the observed cell potential.

This can even be carried out entirely within the well as shown in Figure 8. A long column of salt water 13 is built up through and above the producing formations, either by addition from the surface through the annulus or by raising the level 22 of the inlet to pump 13 above the producing formations and pumping off the oil in the annulus fluid column so that it is replaced by produced salt water.

The pump inlet 22 is then lowered back to bottom and a conditioning agent such as sulfuric acid is distributed through the salt water column 13 by a bailer 60 which is traversed through the annulus. A preferred way of adding the conditioning agent, particularly if the salt-water column is long enough or is being added to from the surface, is to locate the bailer 60 at a conditioning point just above the well test zone and add the agent to the salt water passing by this point during the drawdown and contamination survey.

By whatever way the well fluid column is treated, the resultant log of cell potential as a function of depth, made while drawing down the conditioned salt water past the producing formations and maintaining the proper bottom-hole pressure by fluid additions from the surface, is of the same general character as Figure 5 and has the same significance. The contamination or dilution pattern in the downwardly moving liquid column has the same semi-permanence or stability as the pattern obtained using fresh water in the previous embodiments.

It should be noted that the invention, while so described, is not limited solely to the detection of salt water, using fresh or treated well water as the conditioning liquid. There are wells, for example, in which the connate water resistivity is high enough that salt water is to be preferred for the conditioning liquid, having a contrastingly lower resistivity than the produced well water. The indications obtained by such a variation in technique are, however, analogous to those obtained as above described. It is also possible to locate the exact zones of entry of other fluids in the well such as oil, by using as the conditioning liquid, not water or brine but a material miscible in the same manner with oil as water is miscible with the well brine, but contrasting with the oil in some measurable characteristic such as fluorescence, electrical conductivity, dielectric properties, opacity, and the like.

While our invention has thus been described by giving in detail the sequence of steps by which we arrive at the desired results, it will be apparent to those skilled in the art that certain modifications of these steps are possible without affecting the validity of the results obtained. The invention, therefore, should not be considered as limited strictly to the described procedure, but its scope is to be ascertained from the appended claims.

We claim:

1. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of placing a column of conditioning liquid throughout a producing zone to be tested in said well, flowing said column through said zone, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by formation fluids, all of said steps being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

2. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of placing a column of conditioning liquid throughout and somewhat above a producing zone to be tested in said well, pumping said well from a point near the bottom of said zone to cause said column to move downwardly through said zone, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by formation fluids, all of said steps being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

3. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of replacing a substantial portion of the fluid column in the well by a conditioning liquid which forms a consolidated column extending at least through a test zone in said well, pumping said well to cause said consolidated column to move through said test zone, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by formation fluids, all of said steps

being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

4. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of replacing at least that portion of the fluid column in the well annulus extending through and substantially above a producing zone to be tested with a conditioning liquid miscible with the well fluid of which the ingress is to be located, pumping said well from a point below said zone to draw said conditioning liquid downwardly through said zone, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by formation fluids, all of said steps being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

5. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of continuously flowing an uncontaminated conditioning liquid from outside of a zone to be tested in said well through said zone, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by formation fluids, all of said steps being carried out while mantaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

6. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of flowing a liquid past a conditioning point outside of a producing zone to be tested in said well, adding a conditioning agent to said liquid at said point, then flowing said liquid containing said agent through said zone, and measuring as a function of depth a property of said liquid characterizing the interaction of entering formation fluids and said agent, all of said steps being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

7. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, introducing into the well annulus on top of the fluid column therein a conditioning liquid at a rate which is a substantial fraction of the well-pumping rate, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by formation fluids, all of said steps being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrustion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

8. The method of testing a well to determine lcoations of fluid ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, continuously introducing conditioning liquid into the well annulus at a rate which is a substantial fraction of the pumping rate, until a condition of producing equilibrium is established in which said conditioning liquid flows downwardly past a producing zone in said well and the well formations produce into the well bore at a substantially constant rate, consolidating said downwardly flowing conditioning liquid into a column extending at least through said zone, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by formation fluids, all of said steps after the first being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning liquid into the well formations is positively prevented and said formations are at all times producing their natural fluids into the well bore.

9. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, introducing a conditioning liquid into the well annulus continuously over a period of time, at least until said liquid reaches the well bottom, at a rate which is a substantial fraction of the well-pumping rate, accumulating said conditioning liquid into a consolidated column extending at least through the well producing zone, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by entering formation fluids, while pumping said well to draw down said column through said zone and simultaneously produce formation fluids into said column at their locations of ingress.

10. The method of testing a well to determine locations of fluid ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, introducing a deformable plug into the well annulus on top of the well fluids therein, introducing a conditioning liquid on top of said plug at a rate which is a substantial fraction of the well pumping rate, whereby a substantial portion of the formation fluids in said annulus are removed from said well by pumping, and said bottom-hole pressure is maintained continuously below static, drawing down said conditioning liquid as a consolidated column past the well producing zone while continuing said pumping to cause formation fluids to enter said column, and measuring as a function of depth a property of said conditioning liquid characterizing its contamination by said formation fluids at the locations of their ingress.

11. The method of testing a well to determine locations of water ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, continuously introducing conditioning water contrasting in electrical conductivity with the well water of which the ingress is to be located, into the well annulus at a rate which is a substantial fraction of the pumping rate, until a condition of producing equilibrium is established in which said conditioning water flows downwardly past a producing zone in said well and the well formations produce into the well bore at a substantially constant rate, consolidating said conditioning water into a column extending at least through said zone, drawing said column downwardly through said zone, and measuring as a function of depth the electrical conductivity of said conditioning water characterizing its contamination

by formation water, all of said steps after the first being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning water into the well formations is positively prevented, and said formations are at all times producing their natural fluids into the well bore.

12. The method of testing a well to determine locations of water ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, continuously introducing conditioning water contrasting in electrical conductivity with the well water into the well annulus, at a rate which is a substantial fraction of the well pumping rate, over a period of time substantially greater than that required for the first-introduced conditioning water to reach the bottom of said well, whereby salt accumulations in said well are purged by said conditioning water, consolidating said downwardly flowing conditioning water into a column extending at least through the well producing zone, drawing down said column through said zone, and measuring as a function of depth the conductivity of said conditioning water characterizing its contamination by formation water, all of said steps after the first being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning water into the well formations is positively prevented, and said formations are at all times producing their natural fluids into the well bore.

13. The method of testing a well to determine locations of water ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, introducing into the well annulus on top of the fluid column therein conditioning water contrasting in electrical conductivity with the formation water, at a rate which is a substantial fraction of the well-pumping rate, consolidating said conditioning water into a column extending at least through a test zone in said well, drawing said column down through said zone, and measuring repeatedly as a function of depth the conductivity of said conditioning water characterizing its contamination by formation water, all of said steps after the first being carried out while maintaining a bottom-hole pressure in said well below static, whereby intrusion of said conditioning water into the well formations is positively prevented, and said formations are at all times producing their natural fluids into the well bore.

14. The method of testing a well to determine locations of water ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, continuously introducing conditioning water contrasting in electrical conductivity with the formation water into the well annulus at a rate which is a substantial fraction of the pumping rate, until a condition of producing equilibrium is established in which said conditioning water flows downwardly past the producing zone of said well and the well formations produce into the well bore at a substantially constant rate, consolidating said downwardly flowing conditioning water into a column extending at least through said zone, drawing down said column through said zone, and measuring repeatedly as a function of depth the electrical conductivity of said conditioning water characterizing its contamination by formation water while varying the rate of introduction of additional conditioning water into the well annulus to vary inversely the producing rate of the formations into the well bore, all of said steps after the first being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning water into the well formations is positively prevented, and said formations are at all times producing their natural fluids into the well bore.

15. The method of testing a well to determine locations of water ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, introducing a deformable plug of viscous pumpable liquid into the well annulus on top of the oil column therein, introducing on top of said plug conditioning water contrasting in electrical conductivity with the formation water, at a rate which is a substantial fraction of the well-pumping rate, whereby a substantial portion of the oil column in said annulus is removed from said well by pumping, and said bottom-hole pressure is maintained continuously below static, drawing down said conditioning water as a consolidated column past the well producing zone while continuing said pumping to cause formation fluids to enter said column, and measuring as a function of depth the electrical conductivity of said conditioning water characterizing its contamination by formation water entering said column at the locations of ingress.

16. The method of testing a well to determine locations of water ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure therein below static, placing a substantially continuous column of formation water containing a conditioning agent sensitive to dilution by additional formation water in the well bore throughout and somewhat above the producing zone to be tested in said well, flowing said column through said zone, and measuring in said column as a function of depth a property characterizing the effect of entering formation fluids on said conditioning agent, all of said steps after the first being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of the conditioned formation water into the well formations is positively prevented, and said formations are at all times producing their natural fluids into the well bore.

17. The method of testing a well to determine locations of fresh water ingress therein which comprises the steps of pumping said well to lower the bottom-hole pressure below static, introducing into the well annulus, on top of the liquid column therein, conditioning salt water at a rate which is a substantial fraction of the well-pumping rate, until a condition of producing equilibrium occurs in which said salt water flows downwardly past the producing zone in said well and the well formations produce into the well bore at a substantially constant rate, consolidating said downwardly flowing salt water into a column extending at least through said zone, drawing said column down through said zone, and measuring as a function of depth the conductivity of said salt water characterizing its contamination by entering fresh water from the well formations, all of said steps after the first being carried out while maintaining the bottom-hole pressure in said well below static, whereby intrusion of said conditioning salt water into the well formations is positively prevented, and said formations are

at all times producing their natural fluids into the well bore.

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