

Sept. 20, 1966

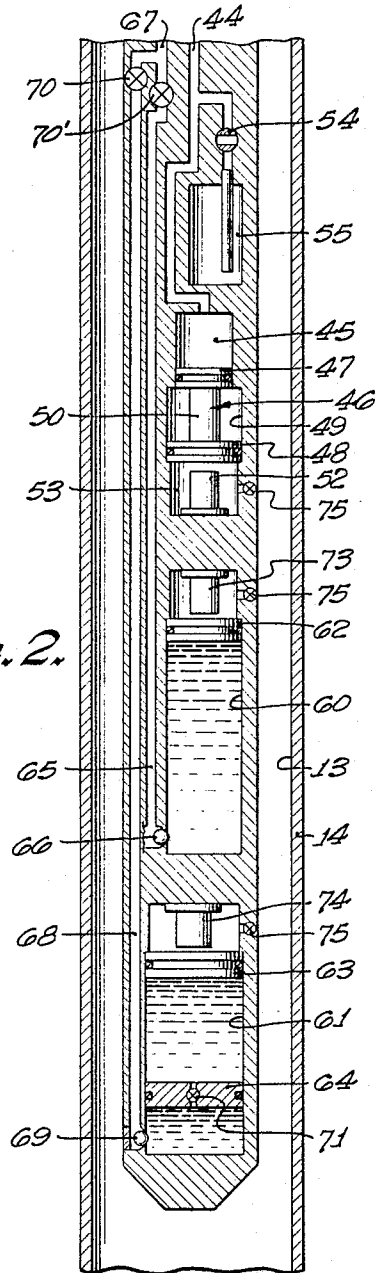
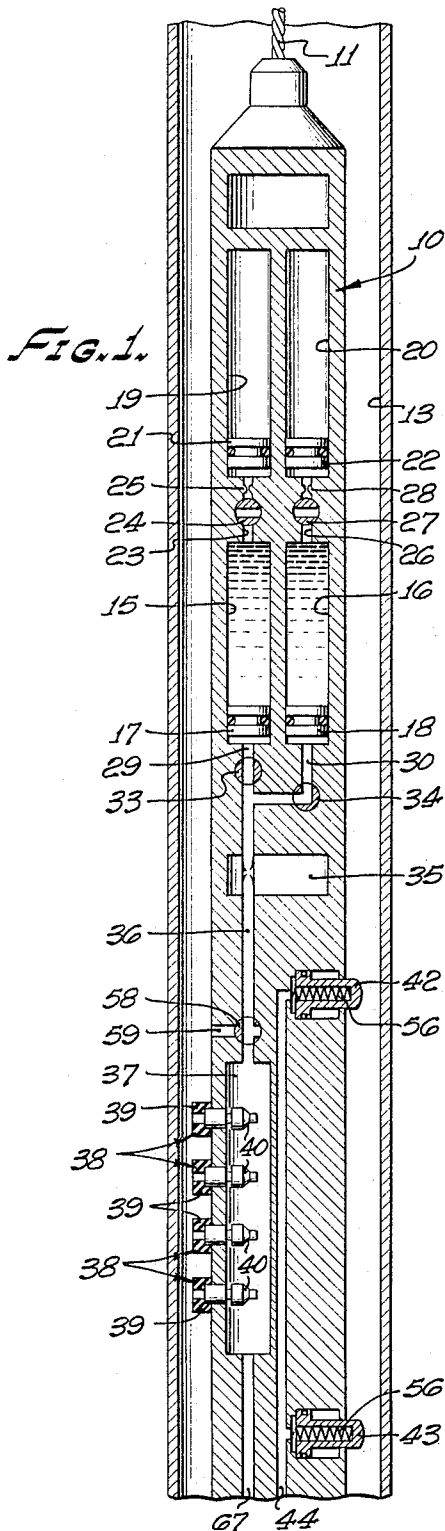
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3,273,647

COMBINATION WELL TESTING AND TREATING APPARATUS

Filed Aug. 19, 1963

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

FIG. 3.

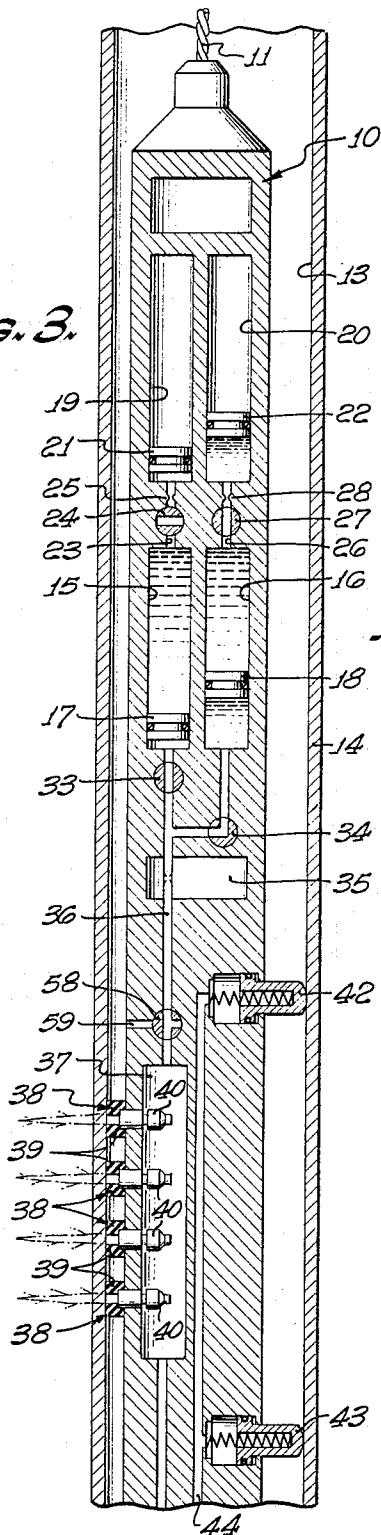
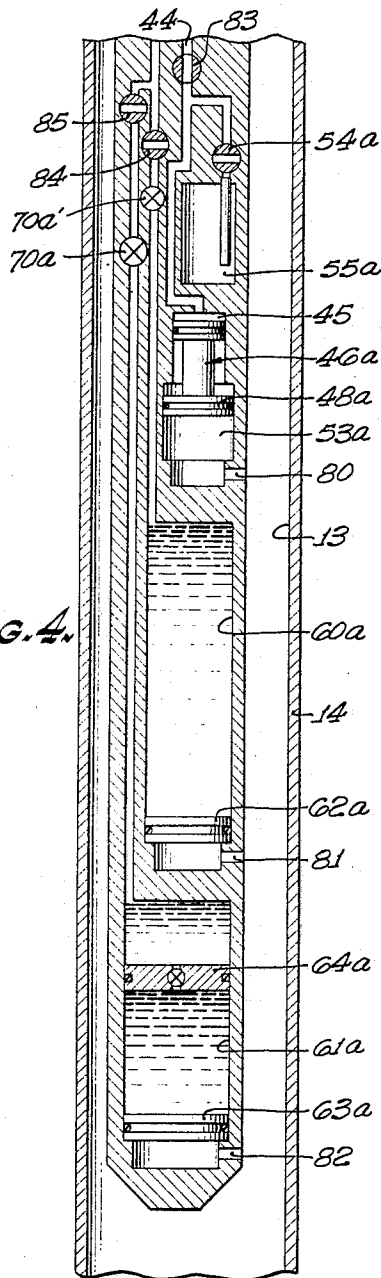


FIG. 4.



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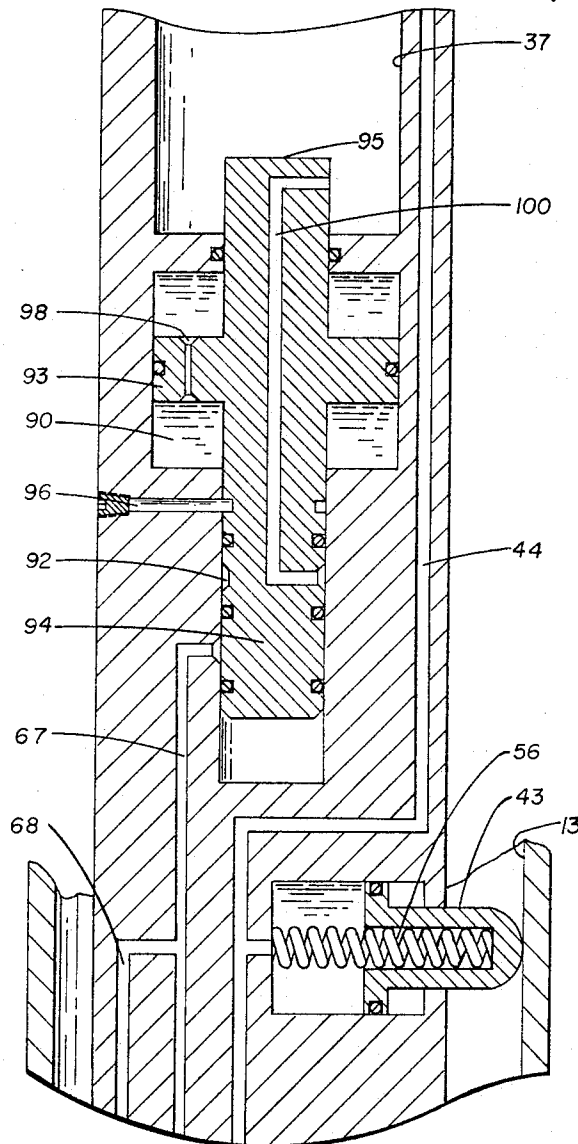


FIG -5-

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COMBINATION WELL TESTING AND TREATING APPARATUS

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6 Claims. (Cl. 166—100)

This invention relates to the testing and treating of wells and is particularly directed to a combination tool adapted to be run into a well bore on a wire line and constructed to perform both well testing and well treating operations.

An important object of this invention is to provide a device of this type having great versatility and capable of performing varied and complex operations in either a cased or an uncased hole, and without removing the device from the well.

This general object is accomplished by providing the device with two sample-receiving chambers and two injection-fluid chambers, all independently controlled from the earth's surface. The operator at the earth's surface may therefore control the time of and the sequencing of the operation of any of these chambers. Thus, the device may be operated to obtain a first sample of well fluid from the formation and then may be operated to perform one or more fluid-injection steps before a second sample of well formation fluid is obtained. Or the operator may carry out a program including a sampling sequence performed between two injection sequences.

Another object of this invention is to provide a well testing and treating device employing gas-generating propellant charges electrically ignitable under control from the earth's surface to provide the power for operating various parts of the device. Thus, the hydraulic system for moving the sealing mechanism into position to isolate a section of the well formation may be powered by such a gas-generating propellant charge. Propellant charges of this type are commercially available and may have the operating characteristics described in the Baker et al. Patent No. 2,640,547, granted June 2, 1953.

Gas-generating propellant charges may also be employed in the device for moving displacement pistons within the fluid-injection chambers, in order to inject fluids of various preselected characteristics directly into the well formation. For example, certain types of fluids are used for sand consolidation purposes.

There are several advantages resulting from the use of gas-generating propellant charges for operating various parts of the device, instead of employing hydraulic pressure as generated by the hydraulic head of bore hole fluids. Among these advantages are the ability of performing injections at superhydrostatic pressures sufficient for carrying out fracturing operations. Another advantage is that the propellant charges are similar and inherently more reliable devices than the valves they replace, providing an over-all, more reliable sampling and treating device. Also, the device may be used effectively at shallow depths or in boreholes having very low hydrostatic head pressures.

Another feature of the present invention relates to controlling the rate of injecting material into the formation to limit the velocity thereof in order to prevent the forming of undesirable void spaces in the formation by jet action.

A more detailed object of this invention is to provide a construction wherein the valves controlling flow of well fluid into the sample chambers are each located in the passage connecting the sample chamber to its respective fluid-displacement chamber. In this location, the valves are isolated from borehole fluids. Since the displacement

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fluid is clean, it is not necessary to perform a cleanup procedure on the sample flow valves when redressing the tool for another run.

Briefly stated, the device embodying various aspects of this invention includes a dual fluid-sampling system located in the upper portion thereof, a sample inlet and injection manifold cavity generally located centrally thereof, and dual injection-fluid chambers in the lower portion thereof, with associated actuation, control and instrumentation means.

Other and more detailed objects and advantages will appear hereinafter.

In the drawings:

FIGURE 1 is a sectional elevation in diagrammatic form, showing a preferred embodiment of this invention;

FIG. 2 is a continuation of the lower end of FIGURE 1;

FIGURE 3 is a sectional elevation in diagrammatic form, showing a modified form of the invention;

FIGURE 4 is a continuation of the lower end of FIGURE 3; and

FIGURE 5 is a sectional, somewhat detailed, view of a time delay valve which may be desirably employed with the modified form of the invention.

Referring to the drawings, the body generally designated 10 is suspended on a wire line 11 and adapted to be lowered into a well bore 13. The well bore 13 may or may not contain a casing 14.

The upper portion of the body 10 contains walls defining a pair of sample-fluid chambers 15 and 16, each having a floating piston 17, 18 therein. A separate displacement-fluid chamber 19, 20, is provided for each of the sample-fluid chambers 15 and 16, respectively. Floating pistons 21 and 22 are positioned within the displacement-fluid chambers 19 and 20. A passage 23 connects the sample-fluid chamber 15 with the displacement-fluid chamber 19, and this passage contains a flow valve 24 and a choke 25. Similarly, a passage 26 connects the sample-fluid chamber 16 with the displacement-fluid chamber 20, and this passage 26 contains a flow valve 27 and a choke 28.

The sample-fluid chambers 15 and 16 are initially filled with clean liquid, for example, water, and the displacement-fluid chambers 19 and 20 initially contain gas under low pressure, for example, air at atmospheric pressure. When the flow valve 24 is opened to permit flow of well formation fluid into the sample-fluid chamber 15 through inlet opening 29, the pressure of the sample fluid acting against the floating piston 17 causes the clean liquid in the chamber 15 above the piston 17 to pass through the valve 24, choke 25, and into the displacement-fluid chamber 19 below the piston 21. Similarly, when flow valve 27 is opened to permit flow of well formation fluid into sample-fluid chamber 16 above the piston 18 to be expelled by way of inlet 30, the pressure of the sample fluid action on the floating piston 18 causes the clean liquid in the sample-fluid chamber 16 above the piston 18 to be expelled through passage 26, valve 27, choke 28, and into the lower end of the displacement-fluid chamber 20 below the floating piston 22. The flow valves 24 and 26, as well as the chokes 25 and 28, are contacted only by clean liquid, and not by the well-formation fluid. The chokes 25 and 28 serve to limit the rate of flow of sample fluid into the sample-fluid chambers 15 and 16.

Shut-off valves 33 and 34 are mounted on the body 10 to close in the fluid samples after they have filled the sample-fluid chambers 15 and 16 below the floating pistons 17 and 18, respectively. These shut-off valves 33 and 34, as well as the flow valves 24 and 27, are independently operable under control from the surface, by means not shown. Electrically operated remote-controlled valves of this type are shown in the copending applica-

tion of Ernest H. Purfurst, Serial No. 211,980, filed July 24, 1962.

The instrument compartment diagrammatically shown at 35 is positioned in the sample-fluid passage 36, leading from the body cavity 37 to the shut-off valves 33 and 34. In this compartment are instruments for measuring the pressure, fluid resistivity, and flow rate of the sample fluid, together with means whereby these measurements may be telemetered to the earth's surface and recorded. The body cavity 37 with its longitudinal row of fluid-sample inlet elements 38 is preferably of the construction shown in the copending application of Francois H. K. Reynolds, Jr., filed concurrently herewith. Each of the elements 38 includes a ring pad 39 mounted on the outer surface of the body 10 and shaped to have sealing engagement with the inner surface of the casing 13. Each of the elements 38 also has an electrically fired jet-charge device 40, adapted to blast a perforation in the wall of the casing into the cement sheath, mud sheath, etc., and into the well formation. Fluid from the well formation flows through the casing perforations into the cavity 37 after the jet-charge devices 40 are fired. In the event the device is to be used in open hole and without casing, the sealing pads and associated elements preferably take the form shown in the copending application of Robert G. Peter, Serial No. 247,067, filed Dec. 26, 1962.

The sample-fluid inlet elements 38 are held in sealing contact with the inner surface of the casing 13 by means of laterally extendible piston elements 42 and 43 located on the body 10 above and below the cavity 37. The parts are shown in this position in FIGURE 3 of the drawings. The piston elements project in a direction opposite to that of the fluid-sample inlet elements 38. The piston elements 42 and 43 are projected laterally to contact the casing 13 when hydraulic fluid under pressure is supplied to them through the passage 44. Hydraulic pressure for extending the piston elements 42 and 43 is supplied from high-pressure chamber 45 by way of passage 44. A pressure intensifier device 46 includes a small-diameter piston 47 sliding in the chamber 45 and a large-diameter piston 48 sliding in the bore 49. The pistons are connected by a heavy rod 50.

In the preferred form of this invention shown in FIGURES 1 and 2, a gas-generating propellant charge 52 is positioned within the firing chamber 53 below the large piston 48 and is electrically fired by a conventional means not shown, controlled from the surface of the earth. When the propellant charge 52 is ignited, the gas pressure in the chamber 53 rapidly increases and moves the pressure intensifier 46 upward to cause hydraulic fluid in the chamber 45 to project the piston elements 42 and 43. After the tool has been used to perform testing or treating operations, or both, as described below, the piston elements 42 and 43 are retracted by opening the dump valve 54 and thereby dumping the high-pressure hydraulic fluid from the passage 44 into the low-pressure dump chamber 55. Hydrostatic pressure of borehole fluids acting on the piston elements 42 and 43 then serves to push them to retracted position, assisted by the internal tension springs 56. At that time, the equalizer valve 58 is opened to connect the body port 59 to the body cavity 37, thereby equalizing the pressure across the pads 39 and thereby facilitate their removal from the casing or well bore.

Injection-fluid chambers 60 and 61 are mounted on the body 10 near the lower end thereof. A floating piston 62 is mounted in the chamber 60 and a floating piston 63 is mounted in the chamber 61. In addition, a valved floating piston 64 is mounted in the chamber 61 above the lower end thereof. A discharge passage 65, provided with a check valve 66, connects the lower end of the injection-fluid chamber 60 to the passage 67 communicating with the cavity 37. Similarly, the discharge passage 68, provided with check valve 69, connects the lower end of the injection fluid chamber 61 to the passage 67 communicating with the cavity 37. Choke or needle

valves 70 and 70' are respectively provided in passages 68 and 65. The valved piston 64 is preferably of the type shown in the copending application of Francois H. K. Reynolds, Jr., referred to above. The valve 71 is shown diagrammatically in FIGURE 2 of the drawings and opens upon predetermined travel of the floating piston 64, to permit discharge of injection fluid between the floating pistons through the discharge passage 68 and into the cavity 37 by way of the choke or needle valve 70. Gas-generating propellant charges 73 and 74 are positioned at the upper ends of the injection-fluid chambers 60 and 61, respectively. These propellant charges may be independently fired under control on the surface by means not shown, the pressure generated serves to move the floating piston downward in its respective chamber to discharge the contents of the chamber into the cavity 37 and out through the elements 38 and perforations in the casing into the well formation.

The check valves 66 and 69 prevent backflow of fluid from the sample inlet and injection manifold cavity 37 into the injection chambers 60 or 61 in the event that the pressure above the floating pistons 62 or 63 should fall below formation pressure, because of cooling and condensation.

Vent valves 75 are provided on the body for each of the chambers containing the gas-generating propellant charges 52, 73, and 74. These vent valves are mounted on the body 10 and are opened after the device has been withdrawn to the surface, in order to relieve pressure in the chambers prior to disassembling the component parts of the tool.

In the modified form of the device shown in FIGURES 3 and 4, the dual sample chambers 15 and 16, the sample-fluid inlet and injection-fluid discharge cavity 37, the elements 38 and the piston elements 42 and 43 are the same as that described above. However, the pressure intensifier chamber 53a and the injection-fluid chambers 60a and 61a are powered by the hydrostatic head of borehole fluids, rather than gas-generating propellant charges. Thus, the lower face of the intensifier piston 48a is exposed to borehole hydrostatic pressure through the body port 80. The floating piston 62a, which moves upward to discharge injection fluid, is exposed on its lower face to borehole hydrostatic pressure through body port 81. The floating piston 63a, which moves upward to discharge injection fluids from the chamber 61a, is exposed on its lower face to borehole hydrostatic pressure through body port 82. The valved floating piston 64a is similar to the valved floating piston 64, described above. The piston elements 42 and 43 are projected laterally when the setting valve 83 is moved to open position, as shown in FIGURE 4. Borehole pressure within the chamber 53a below the intensifier 46a moves hydraulic fluid under pressure through the passage 49 to the piston elements 42 and 43. Retraction of the piston elements, after the tool has performed its functions in the well hole, is accomplished by opening of the dump valve 54a to permit the hydraulic fluid to enter the low-pressure dump chamber 55a.

Injection of fluids from the chambers 60a or 61a is controlled by the injection valves 84 and 85. Choke or needle valves 70a and 70a' respectively restrict the rate of flow of injection fluids from the chamber 61a, and 60a when the valves 85 and 84 are respectively open.

In operation, the body 10 is lowered into the borehole on the wire line 11, and when the desired depth has been reached the piston elements 42 and 43 are extended to bring the pads 39 of the fluid-inlet elements 38 into sealing engagement with the well bore or casing 13. The projection of the piston elements 42 and 43 is accomplished by igniting the gas-generating propellant charge 52 in that form of the invention shown in FIGURES 1 and 2, or by opening the setting valve 83 in that form of the invention shown in FIGURES 3 and 4. The jet-charge devices 40 are then fired to perforate the casing

and to form openings into the well formation, as shown in FIGURE 3. After firing of the jet-charges 40 it is desirable to delay any injection sequence for a time to allow formation fluids to flow into and fill the cavity 37. This flow of formation fluid operates to purge the perforations of debris from the charges, as well as crushed formation particles, and results in perforations having less flow resistance to fluid injection.

The operator at the surface may then perform any one of the following exemplary sequences of operations: (1) testing, (2) testing and cementing, (3) testing, fracturing, testing and cementing, (4) testing, acidizing, testing and cementing, (5) testing, sand consolidating, testing and cementing; and (6) sand consolidating. The testing step is performed by admitting well-formation fluid into one of the sample chambers 15 or 16. The cementing step is performed by injecting fluid cement from one of the injection-fluid chambers into the body cavity 37 and through the elements 38 to plug the casing perforations. The fracturing step is performed by injecting fracturing fluid containing a propping agent from one of the injection-fluid chambers and under the high pressures generated by a propellant charge. Sand-consolidating operations may be performed by sequentially injecting separate fluids from the injection-fluid chambers.

The aforementioned delay between perforating and the commencement of injection may be achieved automatically by providing a valve 85' (see FIG. 5) in lieu of the valve 85. A valve cylinder 90, is provided in communication with the cavity 37. The cylinder 90 is also in communication with a valve chest 92. The valve element has an enlarged portion 93 in sealed slideable engagement with the cylinder 90, an upper portion 95 which extends in sealed slideable engagement into the cavity 37 and a lower valve portion 94 which extends in sealed slideable engagement within the valve chest 92. The valve element is maintained in a normal position shutting off flow from the passageway 67 to the cavity 37 by means of a shear pin 96. In this position, the enlarged portion 93 of the valve element is disposed within the cylinder 90 such that upper and lower metering fluid spaces are provided which are interconnected by an orifice 98. These spaces are filled with a substantially incompressible fluid, e.g., a silicone oil. When the jet charge devices 40 are fired, the ensuing shock wave works on the top of the upper portion 95 causing the same and interconnected enlarged portion 93 to momentarily move slightly downwardly to shear the pin 96. This slight movement (not enough to actuate the valve) is permitted by a small degree of compressibility characteristic of the metering fluid under the enlarged portion 93. After the shock wave has subsided, the pressure within the cavity 37 will drop toward atmospheric pressure and permit formation fluid to enter and fill the cavity 37. Formation fluid pressure in the cavity exerts the actuating force to displace the valve downwardly at a rate controlled by the metering of the metering fluid from below to above the enlarged portion 93 via orifice 98. After a suitable delay to allow formation fluid to fill the cavity 37 (controlled by the metering fluid viscosity and orifice size), the valve 85' moves downwardly to a point where a through-the-valve passageway 100 aligns itself with passageway 67 to establish injection fluid communication to the cavity 37.

It has been found that the best results of sand-consolidation treatments are achieved when the plastic material is injected at a slow rate. If the plastic or wash materials are injected at a high rate, the materials act to jet into the formation and wash undesirable voids in the loose sand material to be consolidated. The purpose of the sand-consolidation operation is to construct a filter about the borehole, and this is done by cementing adjacent loose grains of the sand formation together, but only at their points of contact, so that the filter has substantial permeability. The purpose of the filter is to prevent the well from "sanding up" because of erosion of the formation

incident to the oil-production flow. The desired low flow rates is achieved by the use of the needle valves or chokes 70 and 70' or 70a and 70a', which are positioned in the injection lines leading from the injection chambers to the sample inlet and injection manifold cavity 37. The choke devices thus provided cause a pressure drop which limits the injection fluid flow rates.

When liquid plastic resins, adapted to set up in the presence of a hardening or wash fluid, are employed as the consolidating material, the resin should be kept isolated from the wash fluid as the two are stored in the device in order to avoid premature setting. One way to accomplish this with the device of the invention is to separate the plastic resin and wash fluid within a single chamber 61 by means of a valved floating piston 64. As shown in FIGURE 2, the plastic resins is stored beneath and the wash fluid is stored above the piston 64.

Another way of isolating of the plastic resin from the wash employs an intermediate injection or buffer fluid, such as non-reactive diesel oil, to assure that mixing of the plastic resin and wash fluid will not occur until the plastic has been injected into the formation. As shown in FIGURE 4, the plastic resin may be stored above and the buffer fluid below piston 64a within the chamber 61a. Upon the opening of valve 85, the plastic will be injected first and the buffer fluid second. The wash fluid may be stored in the chamber 60a from whence it may be injected after the buffer fluid has effectively purged the cavity 37 upon the opening of valve 84. Still another way of using a buffer fluid would be to employ two pistons 64a spaced from one another within the chamber 61a such that three fluid spaces are provided. The plastic would fill the space above the upper piston, the buffer fluid would fill the space between the pistons and the wash fluid would fill the space below the lower piston. With this arrangement, the plastic, buffer fluid and wash fluid would be injected in sequence upon the opening of valve 70a.

In the course of the first testing step, the sample-flow pressure, fluid resistivity, and flow rate are telemetered from the instrument cavity 35 to the earth's surface and recorded. After this first testing step, a formation-treating step, such as acidizing or fracturing, may be performed, and then a second test may be taken by admitting well formation fluid into the second sample chamber. During the taking of the second sample, the same measurements are taken and telemetered to the earth's surface and recorded. By comparing the recordings taken during the two sample-taking steps, information is provided to the operator which enables the treatment operation to be evaluated as to its effectiveness. A decision is then made as to whether a similar, large-scale treatment should be performed in the course of completing the well in the particular zone tested.

Another operational advantage of the device arises from the fact that surface control over the sequence and timing of the entire operation reserves to the operator certain options whereby he can alter the sequence or number of the steps in the over-all operation, in accordance with results of previous steps. Thus, if the first sample taken is determined to be oil or gas, as deduced from the recorded information, the operator may inject a treating fluid into the perforations to obtain a relative-productivity indication before and after treatment. If, on the other hand, the first sample is determined to be salt water, as deduced from the recorded information, the operator can inject cement from the other injection chamber, to plug the casing perforations and to complete the operation in this manner.

Having fully described our invention, it is to be understood that we are not to be limited to the details herein set forth, but that our invention is of the full scope of the appended claims.

We claim:

1. A device for injecting fluids into an earth forma-

tion adjacent to the walls of a borehole comprising: a body adapted to be lowered into the borehole, sealing means mounted on said body and adapted to isolate an area of borehole wall and establish fluid communication therewith when urged thereagainst, means on said body propellant for urging said sealing means into engagement with a wall of the borehole, the body having two sample-receiving chambers each connected to said sealing means by a valved passage, respectively, the body also having a chamber containing treating fluid for injection into the formation within said isolated area, means on the body forming a passage connecting said sealing means with the injection-fluid chamber so as to establish communication with said isolated area, and means for displacing injection fluid from said injection-fluid chamber into said formation within said isolated area, whereby separate samples of formation fluid may be obtained before and after injecting treating fluid into the formation.

2. A device for injecting fluids into an earth formation adjacent to the walls of a borehole comprising: a body adapted to be lowered into the borehole, sealing means mounted on said body and adapted to isolate an area of borehole wall and establish fluid communication therewith when urged thereagainst, means on said body including a gas-generating propellant for urging said sealing means into engagement with a wall of the borehole, the body having two sample-receiving chambers each connected to said sealing means by a valved passage, respectively, the body also having a chamber containing treating fluid for injection into the formation within said isolated area, means on the body forming a passage connecting said sealing means with the injection fluid chamber so as to establish communication with said isolated area, and means for displacing injection fluid from said injection-fluid chamber into said formation within said isolated area, whereby separate samples of formation fluid may be obtained before and after injecting treating fluid into the formation.

3. A device for injecting fluids into an earth formation adjacent to the walls of a borehole comprising: a body adapted to be lowered into the borehole, sealing means mounted on said body and adapted to isolate an area of borehole wall and establish fluid communication therewith when urged thereagainst, means on said body including a gas-generating propellant for urging said sealing means into engagement with a wall of the borehole, the body having two sample-receiving chambers each connected to said sealing means by a valved passage, respectively, the body also having a chamber containing treating fluid for injection into the formation within said isolated area, means on the body forming a passage connecting said sealing means with the injection fluid chamber so as to establish communication with said isolated area, and means including a gas-generating propellant for displacing injection fluid from said injection-fluid chamber into said formation within said isolated area, whereby separate samples of formation fluid may be obtained before and after injecting treating fluid into the formation.

4. A device for injecting fluids into an earth formation adjacent to the walls of a borehole comprising: a body adapted to be lowered into the borehole, sealing means mounted on said body and adapted to isolate an area of borehole wall and establish fluid communication therewith when urged thereagainst, means on said body for urging said sealing means into engagement with a wall of the borehole, the body having a sample-receiving chamber connected to said sealing means by a valved passage, the

body also having two chambers each containing a separate fluid for injection into the formation within said isolated area, means on the body forming passages connecting said sealing means with the injection fluid chambers so as to establish communication with said isolated area, means for displacing a first injection fluid from one of said injection-fluid chambers prior to sampling fluid from said well formation, means for displacing a second injection-fluid from the other of said injection-fluid chambers after obtaining a sample of fluid from said well formation.

5. A device for injecting fluids into an earth formation adjacent to the walls of a borehole comprising: a body adapted to be lowered into the borehole, sealing means mounted on said body and adapted to isolate an area of borehole wall and establish fluid communication therewith when urged thereagainst, means on said body for urging said sealing means into engagement with a wall of the borehole, the body having a sample-receiving chamber connected to said sealing means by a valved passage, the body also having two chambers each containing a separate fluid for injection into the formation within said isolated area, means on the body forming passages connecting said sealing means with the injection fluid chambers so as to establish communication with said isolated area, means including a gas-generating propellant for displacing a first injection fluid from one of said injection-fluid chambers prior to sampling fluid from said well formation, and means including a gas-generating propellant for displacing a second injection fluid from the other of said injection-fluid chambers after obtaining a sample of fluid from the well formation.

6. A device for injecting fluids into an earth formation adjacent to the walls of a borehole comprising: a body adapted to be lowered into the borehole; sealing means mounted on said body and adapted to isolate an area of borehole wall and establish fluid communication therewith when urged thereagainst; means connected with said body for urging said sealing means into forced engagement with the wall of the borehole; a chamber in said body containing fluid for injection into the formation within said isolated area; a fluid flow path connecting said chamber and said sealing means so as to fluidly communicate the same with said isolated area, means in said injection fluid chamber for displacing said injection fluid therefrom via said flow path into said formation within said isolated area, and normally closed means in said fluid flow path adapted to open responsive to pressure of formation fluid entering said sealing means, whereupon said means for displacing may operate to displace said injection fluid into said formation within said isolated area.

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