Feb. 11, 1969 D. R. REARDON 3,426,847

FINAL FLOW PERIOD SAMPLE CAPTURING TOOL

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FIG. 1

FIG. 2
FIG. 3
FIG. 4
FIG. 2a
FIG. 3a
FIG. 4a
FIG. 2b
FIG. 3b
FIG. 4b

FIG. 2

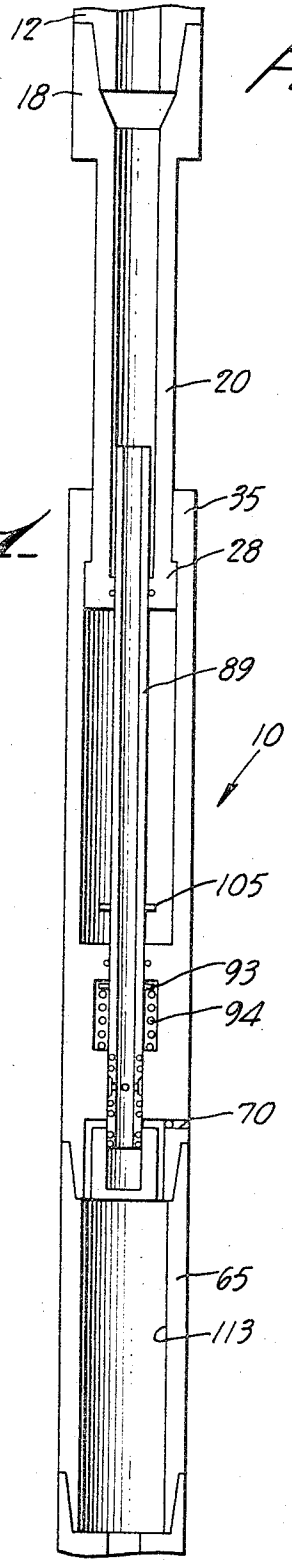


FIG. 3

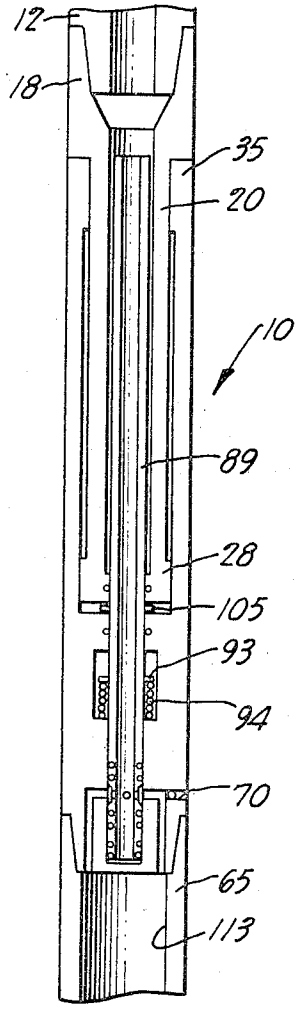
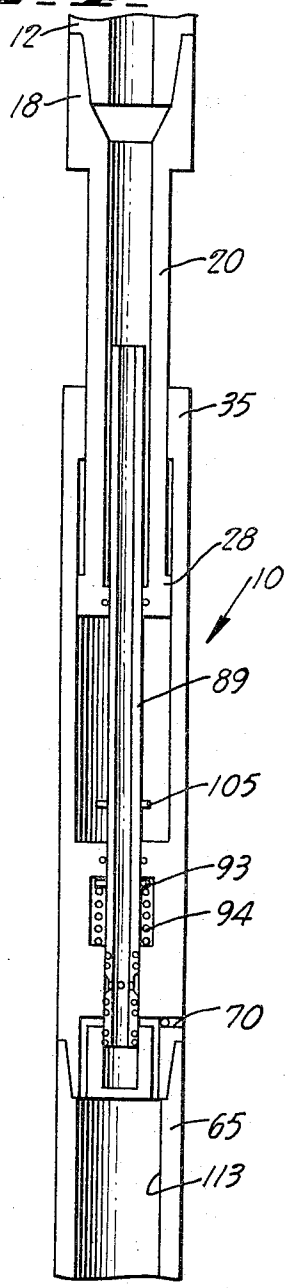


FIG. 4



FINAL FLOW PERIOD SAMPLE CAPTURING TOOL

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FIG. 2a

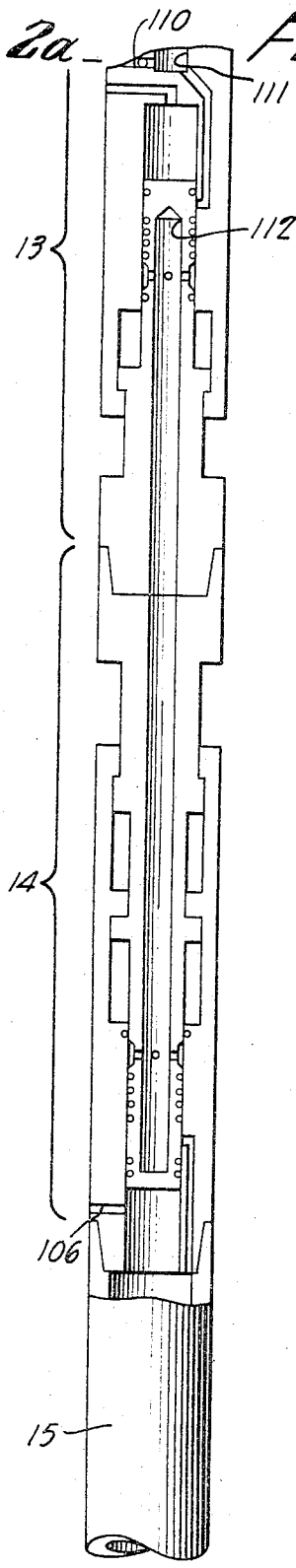


FIG. 3a

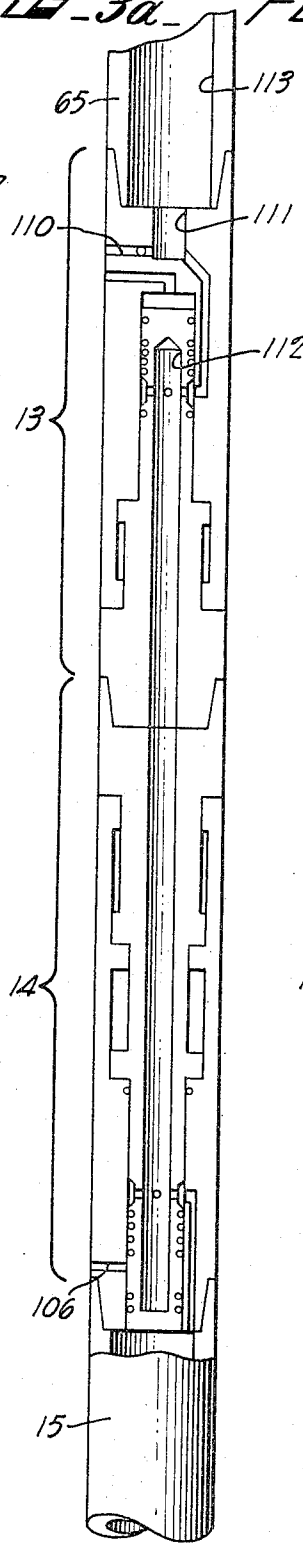
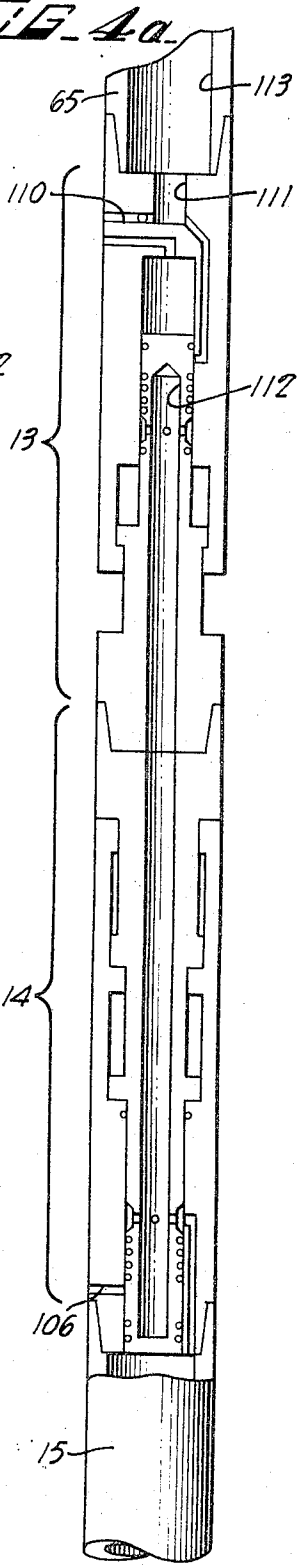


FIG. 4a



FINAL FLOW PERIOD SAMPLE CAPTURING TOOL

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FIG. 2b

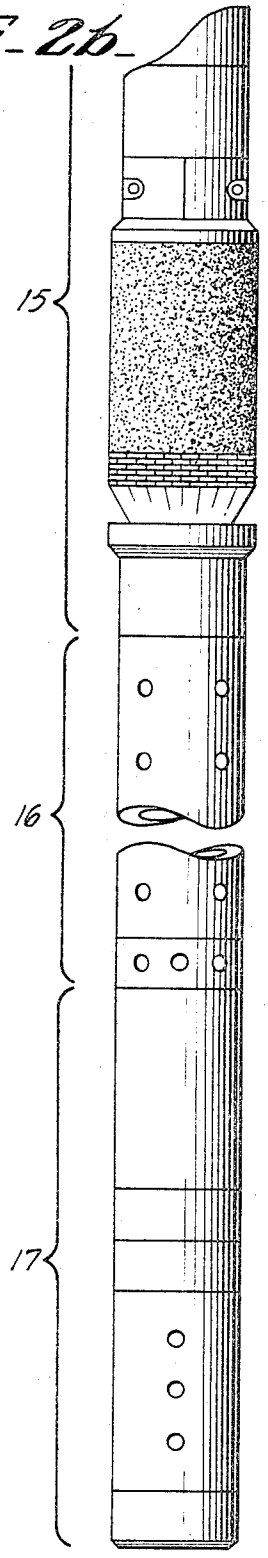


FIG. 3b

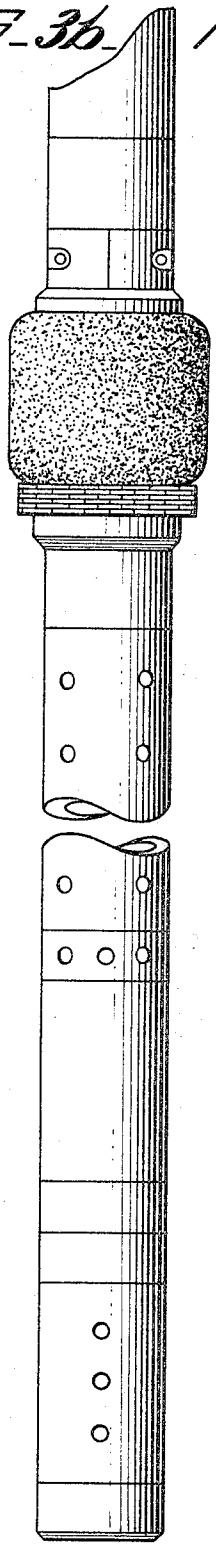
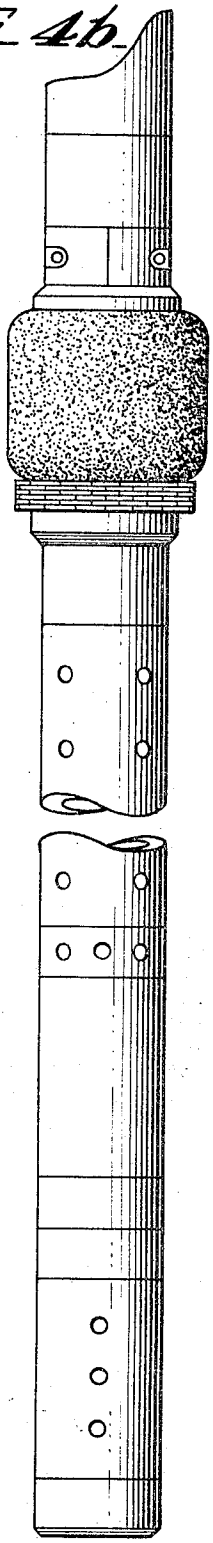


FIG. 4b



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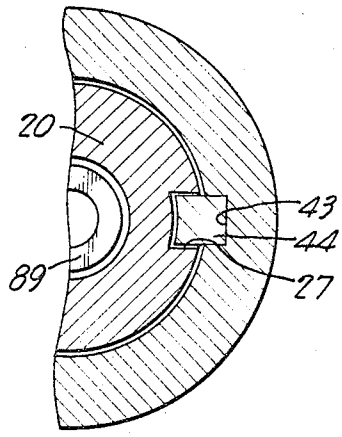
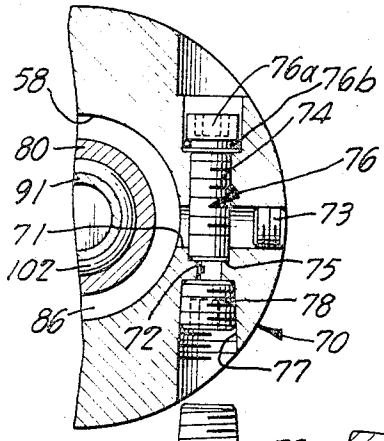


FIG. 8



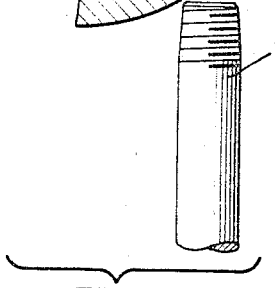


FIG. 7

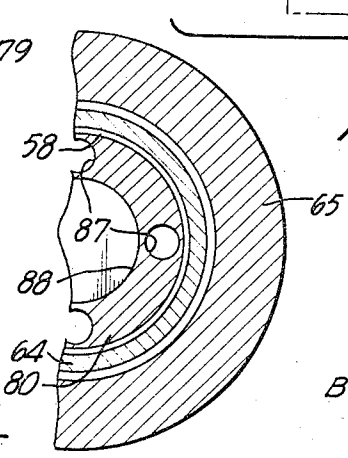


FIG. 6

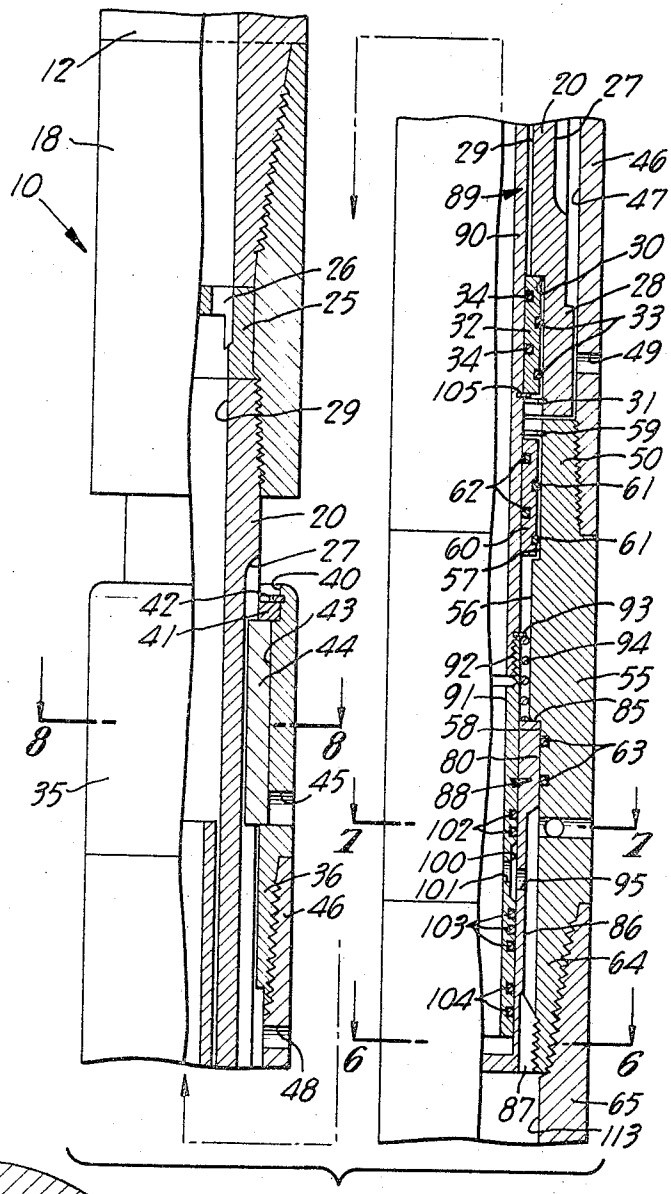


FIG. 5

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3,426,847

FINAL FLOW PERIOD SAMPLE CAPTURING TOOL

Daniel R. Reardon, Garden Grove, Calif., assignor to Cook Testing Co., a corporation of Nevada

Filed June 6, 1966, Ser. No. 555,519
U.S. Cl. 166—150 1 Claim
Int. Cl. G01n 1/10

ABSTRACT OF THE DISCLOSURE

A final flow period sample capturing tool assembly in which the sample is collected in a tubular link in the tool assembly which is independent of the telescopic valve between said chamber and the packer and is also independent of the telescopic valve between said chamber and the tool string supporting the assembly so that in making up the assembly, substantial variations may be made in the volumetric capacity of the sample chamber merely by making a selection between chamber providing links varying in length.

Background of the invention

It is conventional procedure in conducting a deep well oil formation test to employ a test tool assembly which is suspended from a drill string and includes, among other elements, and in order from the top downwards, a shut-in valve tool, a hydraulic valve tool, an open hole packer, a perforated tubing section and a graphic pressure recorder carrier.

The well is normally filled with rotary mud and the drill string is empty when going into the well, with the test tool assembly suspended thereon. The recorder graphically records the pressure of the surrounding fluid below the packer throughout the test. The perforated pipe admits said fluid upwardly through the packer, the hydraulic valve tool and the shut-in valve tool, into the lower end of the drill string, when said valve tools are both open, but the valves of these tools are both closed by the suspended weight of the tool assembly while the latter is being lowered into the well and while it is being withdrawn therefrom.

The first recording of significance is the Initial Hydrostatic Pressure, which is that of the fluids surrounding the recorder carrier when the latter first comes to rest on the bottom of the well.

Each of the valve tools is telescopic, and is opened after the recorder carrier touches bottom, by cautiously continuing the lowering of the drill string. The shut-in tool offers little resistance to opening, and thus its valve opens before that of the hydraulic valve tool, which includes a hydraulic dash pot which delays its opening until sufficient downward pressure has been applied through the valve tools to the packer to set the latter in the well bore and thus pack-off the test area located between the packer and the well bottom.

The setting of the packer and opening of the hydraulic valve tool completes the sealing-off of the test area at the bottom of the well from the column of rotary mud surrounding the drill string above the packer, and opens communication between the packed-off test area and the lower end of the empty drill string.

The next significant pressure in the test, known as the First Initial Flow Pressure, is now recorded.

After a short period during which the pressure in the test area below the packer generally increases slightly due to the rise in fluid level in the drill string, to a value termed the First Final Flow Pressure, the drill string is raised just that amount required to shut the shut-in valve tool, thus shutting in the fluid in said test area so as to develop the pressure latent in the adjacent formation due to fluids

normally flowing from this formation into the well. When this pressure levels off, it is termed the First Initial Shut-in Pressure.

The drill string is now lowered to open the shut-in tool, thereby reconnecting the test area with the interior of the drill string, the pressure thereupon dropping rapidly to a value slightly above the First Final Flow Pressure, and which is termed the Second Initial Flow Pressure.

A flow period of substantial length is now allowed to elapse, during which fluids entering the test area from the surrounding formation flow upwardly through the valve tools and into the lower portion of the drill string. The Second Final Flow Pressure is that recorded at the end of this period, and generally indicates that a sample of substantial magnitude has been received by the drill string.

At the conclusion of the last mentioned free flow period, the drill string is again lifted just enough to close the shut-in tool and seal off the test area against the escape of fluid therefrom. This causes the pressure to rise to a value generally the same or slightly less than the Initial Shut-in Pressure and is known as the Second, or Final Shut-in Pressure. This ordinarily concludes the pressure recordings taken in the formation test, and is followed by withdrawal of the drill string and tool assembly from the well.

When closed against a flow of fluid upwardly therethrough, the hydraulic valve tool opens an auxiliary valve which sets up a communication between the test area below the packer and the well bore just above the packer. This equalizes the pressures in these areas before pulling the packer, and facilitates the latter operation. It is of utmost importance, however, that this function of the hydraulic valve tool be not performed prematurely, but be reserved for the withdrawing of the equipment at the conclusion of the test. The tension in the drill string required to close the shut-in tool must therefore always be substantially less than that which will close the hydraulic valve tool to transmission of fluid upwardly therefrom and open the auxiliary valve for equalizing the pressures above and below the packer.

The closing of the shut-in tool at this stage of the testing operation closes a valve provided therein and prevents downward flow and loss of the fluid sample which has been received during the test in the lower portion of the drill string. Thus this sample is carried upwardly with the apparatus as it is withdrawn from the well. Often this withdrawal consumes enough time to cause a considerable portion of the gas entrained in the liquid of the sample to be lost from the latter during the withdrawal period. Segregation between the aqueous and oil constituents of the liquid also takes place in this sample, so that when an effort is made to analyze the sample by removing and testing a certain portion of the sample which is located close to the test tool assembly at the lower end of the string when this assembly arrives at the top of the well, an untrue picture is presented of the composition of the sample as a whole.

For this reason various expedients have been provided for embodiment within the test tool assembly for completely confining a small fragment of the sample which flows upwardly into the lower end of the drill string, so that this sample may be removed from the test tool assembly at the top of the well, and will give a true picture of the contents of the fluid which was delivered upwardly through the test tool assembly under free flow conditions during the test. The nature of the devices provided for this purpose have limited the size of the sample fragment thus captured at the bottom of the well to approximately 2,500 cubic centimeters. The chamber provided for capturing this sample portion had relatively large surface areas compared with the volume of the

chamber, and when this chamber is opened at the top of the well and the sample portion drained therefrom, there is considerable loss due to the fact that the liquid of this sample portion adheres to said walls, and this is generally the heavier portions of the liquid, and thus distorts the picture produced by the analysis of that part of the sample which it is possible to recover from the tool containing this.

Summary of the invention

It is an object of the present invention to overcome this difficulty by providing a tool which may be combined with the testing tool assembly above described and which will cooperate therewith in the ordinary manipulation of the tool assembly, above described, to capture and completely confine a portion of the fluid sample which has flowed upwardly through said tool assembly right at the end of the final flow period, which sample portion will be substantially greater than that captured by former devices provided for this purpose.

It is also an object of the invention to provide such an accessory tool which is connected at its lower end to the shut-in tool and at its upper end to the lower end of the drill string, and embodies a tubular section providing a sample capturing chamber having a substantial volumetric capacity, which is located directly adjacent the shut-in tool, and a bumper sub, or slip-joint, connected to the upper end of said tubular section and in turn connected to the lower end of the drill string, and which embodies a valve which closes in close coordination with the valve of the shut-in tool as the drill string is lifted at the end of the final flow period, so as to trap, between the closed valve of the shut-in tool and the closed valve of said slip-joint, a sample portion which fills said tubular section.

It is still another object of the present invention to provide such an accessory testing tool in which bleeder means is provided at the top and bottom of said tubular section, for directly connecting the same through pipes leading to analytical equipment at the upper end of the well, and thus separately releasing, under close control, into said analytical equipment, the gaseous, liquid and solid ingredients of said captured sample.

A still further object of the invention is to provide such an accessory deep well testing tool in which the above mentioned valve thereof functions either concurrently with the shut-off valve in the shut-in tool immediately therebelow, or slightly subsequent to the actuation of the valve in said shut-in tool. The purpose of this is to capture the sample occupying the tubular chamber of the tool and hold this until it is bled off for analysis without any change in the pressure existing in that captive sample at the moment it was captured under free flow conditions during the final flow period of the test, at the bottom of the well.

Brief description of the drawing

FIG. 1 is a diagram indicating the vertical relationship between FIGS. 2, 3 and 4 and the (a) series and (b) series figures which constitute successive downward extensions thereof.

FIG. 2 is a diagrammatic vertical sectional view of a preferred embodiment of the oil tool of the invention with the parts thereof in the relative positions which they occupy when said tool is telescopically extended, as when being lowered into or withdrawn from an oil well as a part of an oil well testing assembly.

FIG. 3 is a view similar to FIG. 2, and shows the parts of said tool in telescopically collapsed relation with each other, as when said testing tool assembly is resting on the bottom of the well being tested thereby, with the drill string lowered to impose its weight upon said assembly.

FIG. 4 is a view similar to FIG. 3, and illustrates the parts of said tool related to each other, as when the drill string has been lifted a short distance so as to elongate and shut the shut-in tool of said assembly and then also elongate the telescopic tool of the invention to shut the valve provided therein and thus totally capture a sample of free flowing fluid, which at the moment was flowing through and occupying the fluid sample capturing chamber of said tool.

FIGS. 2*a*, 3*a* and 4*a* are diagrammatic vertical sectional views of a middle portion of the aforesaid testing tool assembly, and illustrating the parts of the tools of said middle portion of said assembly in relative positions which correspond with the relative positions of the parts of the tool of the invention shown respectively in FIGS. 2, 3 and 4.

FIGS. 2*b*, 3*b* and 4*b* are diagrammatic fragmentary elevational views respectively of a lower portion of said oil well testing tool assembly, with the various elements of said lower portion shown as these appear respectively when the parts of the present invention are related to each other respectively as shown in FIGS. 2, 3 and 4.

FIG. 5 is a vertical sectional view drawn approximately to scale of a preferred embodiment of the present invention, with the parts thereof in telescopically collapsed relation, thereby opening the valve therein, as indicated diagrammatically in FIG. 3.

FIG. 6 is an enlarged cross-sectional view taken on the line **6—6** of FIG. 5, and illustrates the peripheral vertical ports in the solid head of the flow sleeve of the invention.

FIG. 7 is a fragmentary enlarged cross-sectional view taken on the line **7—7** of FIG. 5, and illustrates one of the two like bleeder valves of the invention which are provided respectively at the upper and lower ends of the sample capturing chamber.

FIG. 8 is a fragmentary enlarged cross-sectional view taken on the line **8—8** of FIG. 5, and illustrates the mounting of the spline key of the invention.

Description of the preferred embodiment

Referring specifically to the drawings, the invention is seen to comprise a final flow period sample capturing tool **10** which performs its novel functions when united with certain other oil well testing tools to be described hereinafter, in an oil well testing tool assembly **11**. This assembly is lowered into a well (not shown) while suspended on the lower end of a drill string **12**. The tool **10** is connected directly to the lower end of the drill string, and in turn connects to a shut-in tool **13**, which is preferably a multi-shut-in tool, as disclosed in my co-pending application Ser. No. 483,131, filed Aug. 27, 1965, now Patent No. 3,358,767. The balance of the tools in the test tool assembly **11**, in the order in which these are connected serially together and suspended from the shut-in tool **13**, are: a hydraulic valve tool **14**, an open hole packer **15**, a perforated tubing section **16** and a graphic pressure recorder carrier **17**. The elements thus embraced in the tool assembly **11** are conventional with the exception of the tool **10** of the present invention, the shut-in tool **13**, which may be conventional but is preferably a multi-shut-in tool as shown in my co-pending application above identified, and the hydraulic valve tool **14**, which may be conventional but is preferably of the type disclosed in the co-pending application Ser. No. 374,685, filed July 12, 1964 by Wayne N. Sutliff, now Patent No. 3,295,607 entitled, Testing Tool. Reference will now be made to FIGS. 5–8, inclusive, for a specific description of the structure of the tool **10** of the present invention.

At its upper end the tool **10** has a top sub **18** which screws onto the lower end of the drill string **12**, and has threads **19** into which is screwed the threaded upper end of a tubular mandrel **20** so as to trap a bar stop **25** within said sub, the latter having vertical holes **26** allowing liquid to flow freely therethrough. A relatively long keyway **27** is formed vertically in the outer surface of said mandrel, and the latter has an external annular shoulder **28** at its

lower end. Internally, the mandrel **20** has a bore **29** which terminates at its lower end in a short counterbore **30**. Provided in this counterbore near its lower end is an annular recess for receiving a snap ring **31** which confines a tubular O-ring retainer **32** in said counterbore. This retainer has two external annular grooves and two internal annular grooves for retaining O-rings **33** and **34** thereon.

Slidably mounted on the mandrel **20** is a key sub **35**, having at its lower end, an externally threaded pin **36** and, at its upper end, a short counterbore **40** for receiving a key retaining ring **41** and which is recessed to trap a snap ring **42** to hold said ring **41** in place. A key seat **43** is provided internally in the sub **35**, a key **44** being trapped in said seat by the ring **41** with said key also extending into keyway **27** of the mandrel **20**. A key knockout hole **45** is provided in the sub **35** near the lower end of said key to facilitate the removal of the latter when disassembling the tool. Screwed upwardly onto the threaded pin **36** of the sub **35** is the internally threaded upper end of a tubular housing **46**. This housing has an internal bore **47**, which slidably receives the annular shoulder **28** of the mandrel **20**, this housing being internally threaded at its lower end. The housing **46** is also provided with radial mudholes **48** and **49** adjacent its upper and lower ends.

Screwed upwardly into the threaded lower end of housing **46** is the externally threaded pin **50** of a bottom sub **55**. This sub has an internal bore **56**, and upper and lower counterbores **57** and **58**. Near its upper end the counterbore **57** is recessed to receive a snap ring **59** for trapping in said counter bore an O-ring retainer **60**, which is properly grooved to retain external and internal O-rings **61** and **62** respectively. Counterbore **58** is recessed to mount O-rings **63** near its upper end and is internally threaded near its lower end. The bottom sub **55** terminates downwardly in a taper threaded pin **64** onto which screws the internally threaded upper end of a well fluid sample capturing tube **65**.

The tool **10** is provided with an upper fluid sample bleeding device **70** which is incorporated in the bottom sub **55** in two holes **71** and **72** formed therein (FIG. 7). The hole **71** is radial and extends entirely through the wall of the sub. The hole **71** is threaded to receive a screw plug **73** to close the outer end thereof. The axis of hole **72** intersects that of hole **71** and hole **72** has counterbores **74** and **74***a*, the first of which intersects hole **71** to provide a valve seat **75**, the counterbore **74** being tapped to receive a threaded valve plug **76** which is ground at its end to fit valve seat **75** and thus form bleeder valve **70** by which escape of fluid under pressure outwardly through hole **72** may be controlled by the rotation of said plug. Plug **76** has a head **76***a* which is received by counterbore **74***a* and has an O-ring **76***b* forming a seal between plug **76** counterbore **74***a*. A threaded counterbore **77** is provided in hole **72** on the opposite side of valve seat **75**, this counterbore being normally closed by screw plug **78**. The latter plug may be removed (for reasons to be made clear later) and replaced by the threaded end of a pipe **79**, shown in FIG.7 in alignment with counterbore **77**.

A flow sleeve **80** is slidably received in the lower counterbore **58** of the sub **55** so that the upper end of said sleeve engages the shoulder **85** formed at the upper end of said counterbore and makes sealing engagement with the O-rings **63** which are recessed into said counterbore. The flow sleeve **80** is externally threaded at its lower end to screw into the internally threaded lower portion of counterbore **58** of sub **55**, and is provided with an extensive annular recess **86** formed in the external surface thereof, which recess communicates at its upper end with hole **71** of the bleeder valve **70** and at its lower end with a series of holes **87** which communicate between said recess and the lower end of said sleeve.

This sleeve has a blind bore **88** extending downwardly from the upper end thereof, the diameter of which bore is approximately equal to the internal diameter of O-ring retainers **32** and **60**. A wash pipe **89** comprising upper and lower sections **90** and **91** which are screwed together by threads **92** slidably fits within the bore of flow sleeve **80** and within said O-ring retainers. Trapped between the upper and lower sections **90** and **91** of wash pipe **89** is a ring **93** which confines a coiled spring **94** between this ring and the upper end of flow sleeve **80**. Holes **95**, preferably four in number, are provided in the wall of flow sleeve **80** opposite the annular recess **86** thereof, and in a given radial plane, these holes being adapted to communicate with an annular recess **100** formed externally in lower wash pipe section **91**, the latter section also having a corresponding number of holes **101** which communicate between said recess and the interior of the wash pipe. The outer surface of wash pipe section **91** is grooved to allow for mounting thereon a pair of O-rings **102** which are disposed above recess **100**, three O-rings **103**, which are disposed below said recess and a pair of O-rings **104**, which are spaced downwardly a substantial distance below the group of O-rings **103**.

The upper section **90** of the wash pipe **89** is suitably recessed externally to receive a snap ring **105** which is adapted to be engaged by the O-ring retainer **60** when the tool **10** is telescopically collapsed, so as to force the wash pipe **89** downwardly, compressing spring **94** and bringing annular recess **100** opposite holes **95** in the flow sleeve **80**, thereby opening the slide valve formed by the structure of tool **10** above described, and permitting a ready flow vertically between the space within the sample capturing tube **65** and the interior of the wash pipe **89** which opens upwardly into the lower end of the drill string **12**.

When the tool **10** is telescopically extended, the O-ring retainer **32** travels upwardly with the mandrel **20**, thus relieving the snap ring **105** of downward pressure, and permitting the wash pipe **89** to be lifted by expansion of the spring **94**, thereby withdrawing the portion of the wash pipe containing the annular recess **100** from registry with the holes **95** of the flow sleeve and thereby closing said sleeve valve and completely shutting off communication between the upper end of sample capturing tube **65** and the interior of wash pipe **89**.

A lower fluid sample bleeding device **110** is provided in the shut-in tool **13** connecting with a passage **111** therein which leads upward from the valve **112** of said tool to the lower end of a sample confining chamber **113** provided by tube **65**. The bleeding device **110** is identical with the bleeding device **70** provided in tube **65** and above described.

Operation

The manner in which oil tool **10** of the invention operates in performing its novel function will be manifest in the following description of a typical oil well test performed by the oil well testing tool assembly **11**. While being lowered through the rotary mud filling the oil well into its testing position at the bottom of the well, the assembly **11** appears as shown in FIGS. 2, 2*a* and 2*b*. That is, each of the extensible tools **10**, **13** and **14** embodied in the assembly **11** is telescopically extended so as to close the valve in that tool which controls lengthwise passage of fluid through said tool. By close observation of the rig scales which indicate the weight of the drill string and the tool assembly suspended therefrom, the rig operator becomes aware immediately when the lower end of the tool assembly **11** comes in contact with, and is supported by, the bottom of the well. From this point, the drill string is carefully lowered that distance necessary to telescopically collapse tool **10** and shut-in tool **13**, thereby placing a substantial pressure on hydraulic valve tool **14** and the hydraulic dash pot embodied therein so that this pressure is transmitted through the tool **14** to the open hole packer **15**, causing this to expand from the condition in which it is shown in FIG. 2*b* to the condition in which it is shown in FIG. 3*b*, in which

said packer makes a fluid-tight engagement with the wall of the well and effectively shuts off any flow vertically of fluid between the packer and the well wall. The downward pressure on the packer to set this is continued until the hydraulic valve tool **14** has become telescopically collapsed so that the valves controlling vertical flow of well fluid through tools **10, 13** and **14** are all open.

The successive vertical manipulations of the drill string described in the preamble of this case are now carried out to obtain the sequence of pressure recordings desired in the test. Incidental to these manipulations and during the periods when the valves of these tools are open, and which are known as flow periods, fluid discharged by the oil-bearing strata beneath the packer enter the perforated tubing **16** below the packer and flow upwardly through the various tools of the assembly **11**, including the final flow period sample trapping tool **10** of the invention, so that the sample capturing tube **65** of this tool is completely filled with this fluid. This final flow period, as already noted, concludes with the rig operator lifting on the drill string **12** so as to successively close the valves in the shut-in tool **13** and the sample trapping tool **10**. The closing of the valve in hydraulic valve tool **14** may be now delayed while a final shut-in pressure is taken. The closing of hydraulic valve tool **14** at the conclusion of this final shut-in period uncovers a port **106** which admits rotary mud surrounding the tool to the central passage thereof leading downwardly through the packer **15** and outwardly through the perforated tubing **16**, thereby equalizing the pressures existing above and below the packer **15**. This equalization of pressures allows the packer **15** to readily contract in response to the upward pull applied thereto by the withdrawal of the drill string **12**, so that the entire assembly **11** is removed from the well with the drill string.

When the testing tool assembly **11** reaches and is withdrawn from the top of the well, the fluid sample captured by the tool **10** is still completely confined in said tool so that by suitable manipulation of the bleeding devices **70** and **110**, practically the entire sample, including gaseous, liquid and solid elements, is subjected to analysis, thus giving a relatively true picture of fluid flow conditions at the bottom of the well being tested.

By virtue of the fact that the sample capturing tube **65** of the present invention constitutes a separate link in the testing tool assembly **11**, this tube may be made in various lengths, and thus provide the opportunity for varying the volumetric capacity of the sample confining chamber **113**, whereby a sample of any desired size may be captured during a test.

The tool **10** of the present invention also provides the great advantage of assuring that each sample thus captured of whatever size represents a true cross-section of the fluid flowing freely from the oil-bearing strata being tested at the bottom of the well, by virtue of coordinately and in rapid succession shutting the valves through which said fluid is flowing into and from the sample confining chamber **113**.

I claim:

1. In an oil well test tool assembly, suspended when in use from the lower end of a drill string, the combination of: an open hole packer; means for setting said packer in an open hole to pack off an area in said hole below said packer for test purposes and cause a flow of well fluid from said test area upwardly through said tool assembly; means located above said packer and providing a sample capturing chamber of substantial volumetric capacity; a first telescopically operable valve means provided in said assembly and interposed as a connecting telescopic link between said packer and said chamber providing means; a second telescopically operative valve means provided in said assembly and interposed as a connecting telescopic link between said chamber providing means and said drill string, both of said valve means being closed when said assembly is supended from said drill string and open when said assembly is set down on the bottom of a well to expand said packer and accomplish a testing operation, well fluid under the latter condition flowing from the test area upwardly through the packer and through said first valve means and said sample capturing chamber and filling the latter, the withdrawal of the drill string at the conclusion of the test coordinately closing said first and second valve means so as to capture and completely confine in said chamber a fluid sample, said sample chamber providing means connecting at its opposite ends to said first and second valve means but being functionally independent of the valve mechanisms of said valve means, whereby sample chamber providing means varying substantially in dimensions and volumetric capacity may be optionally employed in said assembly without modification of said valve means.

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